IN TWO SECTIONS—SECTION ONE

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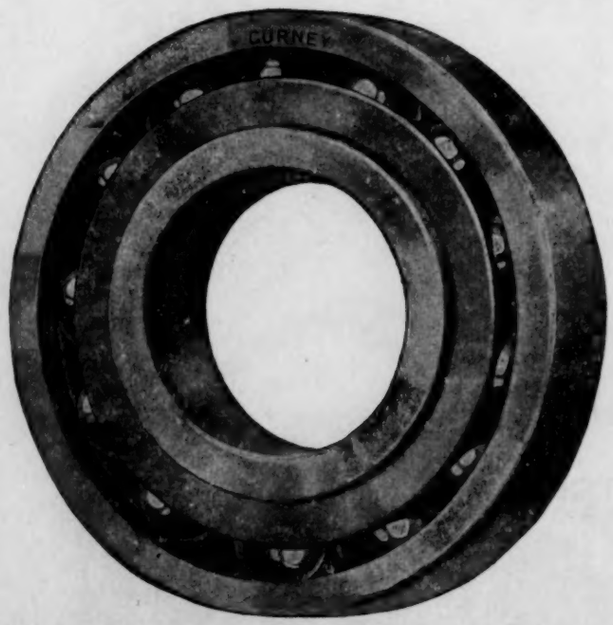

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Pulverized Coal as a Fuel

This Paper Together With the One Which Follows, on Pulverized Coal for Stationary Boilers, and the Discussion Thereon, Represent the Predominating Thought of the Fuel Session Held During the Spring Meeting

By N. C. HARRISON,[1] ATLANTA, GA.

This paper first reviews some of the uses of pulverized coal in the industries—such as the cement, steel and copper industries, and then gives a technical definition of pulverized coal, describes the process by which it is prepared for use and furnishes a table of cost of preparation. The pulverized-coal-burning open-hearth steel plant of the American Iron & Steel Manufacturing Co., Lebanon, Pa., is described and the advantages of pulverized coal, compared with producer gas as a fuel for open-hearth furnaces, are listed.

The use of pulverized coal in stationary boiler plants is discussed, five determining factors in the successful operation of such a plant being taken up in detail. As compared with mechanical-stoker plants the advantages of the pulverized-coal plant are enumerated and certain precautions to be observed with the latter type of plant are brought out.

A report of a test of a 468-hp. Edge Moor boiler with pulverized-coal equipment is included in the paper and the efficiency obtained is compared with the efficiency of a stoker-fed boiler in the same plant, a greater net efficiency being found in the pulverized-coal plant. The paper concludes with a statement of some advantages obtained in the pulverized-coal plant.

THE gradual disappearance of fuels, like natural gas, and the shortage in the supply of crude oils, have compelled in recent years a consideration of pulverized coal as a fuel. Pulverized coal was first used in the United States about twenty-six years ago for the economical burning of cement rock in the rotary kilns of the portland-cement industry and the growth of the industry has had a great bearing on the development and use of pulverized coal. Because of this growth pulverizing machines were also brought to their present high state of development, for in the manufacturing of cement not only is the coal pulverized but for every barrel of cement manufactured (weighing 380 lb.) there are required about 600 lb. of raw material such as limestone shale or cement rock and 380 lb. of clinker produced by the kilns, all of which must be pulverized in order to make the finished product. As there are a hundred million barrels of portland cement made in this country annually, these figures will give one a reason why pulverizing machines have been so highly developed. Fine grinding of the raw material means reduction in the quantity of fuel required and also makes possible the highest quality of the finished product, so far as the chemical analysis or combination is concerned. Fine grinding of the clinker means increased strength for the reason that the hydraulically active units in cement are in direct proportion to the percentage of fine or impalpable powder in the finished product.

The application of this form of fuel has been gradually taken up by engineers connected with other industries, and its recognized value is such that the steel industry today is using in the neighborhood of two million tons of pulverized coal annually in various types of furnaces such as open-hearth, heating, puddling, soaking pits, continuous-heating, reheating, annealing, and forging furnaces.

The copper industry is also using between one and two million tons per year in ore-roasting furnaces, reverberatory and copper-melting furnaces of all types. Large amounts of pulverized coal are used in rotary kilns (other than the cement industry) for the desulphurizing and roasting of various grades of ores; for nodulizing blast-furnace flue dust so as to make available products heretofore very expensive to recover; for burning lime to oxide of lime for use in open-hearth furnaces; for burning dolomite for open-hearth furnaces; and for the calcining of various minerals, from which are obtainable such commodities as plaster of paris, stucco, potash, etc. A total of approximately 10 million tons of pulverized coal are burned annually in the United States in the above industries.

A still further and very important development is now going on, which will, when it attains its growth, require more pulverized coal than probably all of the other industries combined, and that is in its application to locomotives, particularly in the West. There is still another field in which enormous quantities of this fuel will be used and a field in which we are all concerned, and that is in the generation of power in stationary power houses.

Practically any coal can be burned in pulverized form with a proper furnace and burning equipment. Each application however must necessarily be governed by the quality of the fuel available in the district in which it is made. Generally speaking, the coals which give the most satisfactory results are those in which the ash content is less than 10 per cent, the volatile averaging between 30 and 40 per cent and the fixed carbon between 40 and 50 per cent. The sulphur content should be low although coal with a sulphur content running as high as 4½ to 5 per cent is being burned in pulverized form under boilers and without any detrimental results. The ash should have a high melting point. These statements, however, are tentative, as most excellent results have been obtained from all sorts of coals, differing widely from the ideal analysis stated.

What is Pulverized Coal?

From a technical standpoint pulverized coal is that coal which is properly dried, crushed and pulverized so that the product contains the highest percentage of impalpable powder. Merely powdering coal does not fulfill the requirements. Coal must be pulverized so that at least 95 per cent will pass through a 100-mesh sieve having 10,000 openings to the square inch, or in terms of dimension 95 per cent must be less than one two-hundredth of an inch cube.

The average person does not fully realize to what a high degree of fineness it is possible to reduce the coal today by pulverization. The finer the coal is pulverized the more efficiently it can be burned and the more readily it will be diffused when mixed with the air for combustion and fed into the furnaces.

Pulverizing certainly does not change the nature of the coal, but it does change its form to a certain extent in that the coal is changed from a solid into a fuel having liquid properties. As the coal is pulverized it is mixed with air, and when handled in the conveyor it flows like water; when fed to the furnaces it is more or less like a gas, and the furnaces must be designed to burn a gaseous mixture.

Description of a Coal-Pulverizing Plant

A pulverizing plant consists of three main units: a crusher, a crushed-coal drier and a pulverizer, the number of each depending on the size of the plant. The coal is dumped in a track hopper and conveyed by either a belt or apron conveyor into a hopper feeding a single-roll coal crusher, or where slack coal is at hand, direct to an elevator pit. After being crushed to about one inch in diameter, it passes by gravity to an elevator pit, where it is taken by bucket elevators to the drier storage bin. Automatic weighing scales may be installed if desired before the drier storage bin. Magnetic-separator pulleys are also installed (where a belt

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[1] General Supt., Atlantic Steel Company, Atlanta, Ga. Mem. Am. Soc. M. E.

conveyor is used from the track hopper) to remove iron or steel scrap in the shape of nuts, bolts, pick-points, wedges and such foreign matter, which would interfere with the pulverization.

From the drier storage bin the coal passes to a coal drier. This drier must be of a size to deliver the required quantity continuously and thoroughly dried. The drier is heated either by hand firing on grates or by pulverized coal, so arranged in either case to avoid igniting the drying coal. The cylinder of the drier is rotated by power, either a small motor or line shaft being used. The dried coal falls from the drier through a chute into the pit of an elevator. In this chute the coal passes over another magnetic separator to remove any pieces of metal which might be left in the coal and which were not removed by the magnetic separator previously mentioned.

This elevator carries it to a storage bin set aloft for supplying the pulverizer. By spouts and gates the coal is permitted to enter the pulverizer as desired. This pulverizer grinds the coal to the fineness required. From the pulverizer the coal is conveyed in various ways to the pulverized-coal bins. With the type of mill used at the plant of the Atlantic Steel Company, Atlanta, Ga., the pulverized coal is carried by spouts from the mill to the pit of an elevator, which carries it aloft to the screw conveyor, and the latter feeds the pulverized-coal bins. In another type of mill the finely pulverized coal is conveyed by suction fan from the mill to a cyclone separator, properly located over the pulverized-coal storage bin. This separator will allow the coarser particles to fall back to the mill to be reground, while the fine dust passes to the storage bin. No fine-dust elevator is necessary with this mill.

These pulverized-coal storage bins are of a capacity proportional to the service and hold a supply in excess of the amount required in the intervals when the grinding is not going on. Thus the mills may supply in eight to ten hours all that the furnaces may use in 24 hours.

If the pulverizing plant is located within 200 ft. of the furnaces and the furnaces are of large capacity, these storage bins are located directly at the furnaces, but if there are numerous small furnaces located at a considerable distance from the pulverizing plant, then the storage bins are located at some central point and the pulverized coal conveyed from these points to the various furnaces by means of one of three methods: first, screw conveyor; second, in a mass by means of compressed air; third, in suspension in a current of air.

Costs of Pulverizing Coal

The cost of pulverizing coal depends upon four items: first, the amount of moisture that must be expelled from the coal before pulverizing; second, the cost of labor; third, the cost of coal delivered at the pulverizing plant; fourth, the cost of electricity. Table 1, issued by a pulverized-coal engineering company, gives the cost of pulverizing plants, including buildings, and costs of pulverizing coal in plants of capacity from 10 to 250 tons per day. These figures include all costs, except interest and depreciation, in the pulverizing plant proper, and deliver the dust from the top of the last elevator to the screw conveyor, which feeds the pulverized-coal storage bins.

TABLE 1 COSTS OF COAL-PULVERIZING PLANTS AND COSTS OF PULVERIZING COAL PER TON NET

Tons daily	Total cost pulverizing per ton, dollars	Cost of plant including building, dollars
10	0.56	31,000
20	0.51	31,000
30–40	0.49	31,000
50–90	0.39	37,000
100–130	0.34–0.33	45,000
140–180	0.32	50,000
190–250	0.30	62,000

Pulverized Coal in Metallurgical Furnaces

The development and use of pulverized coal in this country has primarily been due to its application in the cement industry and its gradual application to other types of metallurgical furnaces. Marked economies, and in some cases increased production, have been obtained from this fuel and within the last few years it has been applied very successfully to various kinds of heating furnaces, including forging, continuous-heating, busheling, puddling and open-hearth furnaces. Pulverized coal is also being used on continuous-heating furnaces with very gratifying results, and as a fuel for soaking pits its promises to be used more extensively in the future.

One of the first applications of pulverized coal to the various types of metallurgical furnaces was made by the American Iron & Steel Manufacturing Co., now the Bethlehem Steel Co., Lebanon, Pa., at whose plant this form of fuel was successfully applied to heating, busheling and puddling furnaces, this being practically the first attempt to apply it to the iron and steel industry. Taking into consideration the knowledge obtained from the experience at the above-mentioned plant, and also that obtained from other installations, it has been found that furnaces can be successfully operated by various methods of applying this fuel. Each type of metallurgical furnace presents different requirements as to the kind of burners to be used. Probably the greatest recent development in its use has been as a fuel for open-hearth furnaces and boilers.

All open-hearth furnaces using pulverized coal as a fuel are of the reversing type. There has been only one exception in this country to this, as far as the writer knows, and that exception was at the plant of the American Iron & Steel Manufacturing Co., Lebanon, Pa., where they fired their open-hearth furnaces from one end only. On the other end they installed waste-heat boilers and economizers. As an open-hearth proposition this turned out to be a failure, but as a waste-heat boiler proposition it was a wonderful success. During 1918 they remodeled these furnaces and fired them from both ends.

In the open-hearth furnaces the pulverized coal is delivered into storage bins located at each end of the furnace. On the bottom of these bins are screw feeders, driven by variable-speed motors for supplying the amount of coal desired. This carries the coal by gravity into the burner pipe. These burners are usually a combination of compressed air at from 60 to 80 lb. pressure and fan air at about 8 oz. pressure. In some cases compressed air alone is used as the medium for conveying this coal into the furnaces. The hearth of a pulverized-coal open-hearth furnace is practically the same as the hearth of any other open-hearth furnace but the uptakes, slag pockets and checker chambers are entirely different. The uptakes are made as small as possible so as to hold the gases in the furnace as long as possible without blowing, and the slag pockets are made large so that the gases will have a slow velocity going through them, thereby depositing a large percentage of the heavy particles that are in the outgoing gases. On account of this heavy deposit, removable slag pockets, or very deep stationary pockets, should be used, so as to collect this accumulation over the run of the furnace. Where removable slag pockets are used, they are taken out and cleaned and replaced about every two weeks.

Only one checker chamber is needed on each end of the furnace. If the checker chamber is large enough, these chambers should be built up with large tiles and laid in such a manner as to form vertical flues, having openings of at least 6 by 9 in., or better, 9 by 11 in. In some cases, no checkers at all are used but the chambers are filled with baffle walls with openings from the outside, so that the accumulation between these baffle walls can be raked out. All passages from slag pockets to stack must be as straight as possible and wherever any bends must be made, some agitating device should be installed at these points. The reversing valves are usually of the mushroom and damper-slide type.

The best coal for use in pulverized form in open-hearth practice is a bituminous coal as high in volatile matter as possible, and preferably low in ash. It should never contain below 32

per cent of volatile, nor more than 8 per cent of ash. For open-hearth furnace use it is necessary that the coal be as finely ground as possible and it should be so fine that about 97 per cent will pass through the 100-mesh sieve, preferably 90 to 93 per cent and not less than 85 per cent through the 200-mesh sieve, and from 70 to 75 per cent through the 300-mesh sieve.

This very fine pulverization is necessary for quick combustion and for the removal of sulphur in the coal; and in order to obtain this complete combustion before the flame strikes the bath, some 6 or 8 ft. are necessary from the end of the burners to the bath.

Pulverized Coal vs. Producer Gas

The advantages and disadvantages from the use of pulverized coal, as compared to gas producers, as a fuel for open-hearth furnaces, from observation of its use up to date are as follows:

a Since the coal is of a more even chemical composition all the heat units are consumed in the furnace, while in the case of the gas producer from 18 to 25 per cent of the heat units are lost in the producer itself when converting the coal into gas. This will result in a greater number of heats per week.

b Open-hearth furnaces using powdered fuel operate on a very low fuel consumption equal to the best producer-gas practice, and much better than the average of the older plants in this country; at the writer's plant (The Atlantic Steel Company, Atlanta, Ga.) about 50 per cent less.

c Coal can be pulverized in plants of about 100 tons daily capacity and delivered to the furnace for approximately 50 cents per ton, which is about the same as the costs for gasifying coal in gas producers.

d Although the use of this fuel in metallurgical furnaces has been developed only about 75 per cent, it is believed that this development is steadily increasing. In the writer's plant the pulverized-coal open-hearth furnace has been shut down more often than the producer-gas furnace of the same size. This has been due to checkers and slag pockets filling up with cinders and slag after about 80 heats; these troubles, however, are being gradually overcome by decreasing the size of the uptakes and enlarging the slag pockets, thereby holding the gases in the furnace longer and passing them slowly through the large slag pockets, so that the heavy particles can settle, and now only the fine particles are going to the checkers, which particles are being blown off daily by compressed air. By these means it is expected to get a much longer life out of the checkers, and consequently longer runs out of the furnace, since the filling up of the checkers has always been the deciding factor in the length of run of the furnace.

e Sulphur does not give any trouble as long as there is a good draft and the furnace is working hot, as this plant is now using over 1 per cent sulphur in its coal and getting good results, although when checkers get clogged up and the furnace begins to blow, due to lack of draft, there is trouble with the bath taking up sulphur. This takes place during the last week's run of the furnace, just before it goes down for repairs.

f The pulverized-coal open-hearth furnace is under complete control of the first helper as to the amount of coal being used at all times, air blast and temperature.

g The flame, using the same coal as on gas producers, is hotter, which allows the use of a greater percentage of scrap per ton of steel, thus reducing the consumption of high-priced pig iron.

h The finished steel is quieter in the molds, due to not being overly oxidized, as the coal coming directly in contact with the bath has a greater reducing action. All gas-house troubles are eliminated (cleaning fires, burning out flues, etc.) although the pulverizing plant must be given attention as to dryness and fineness of coal.

i Up to date, the refractory costs have been very much greater on the furnace using pulverized coal than on the gas-producer furnaces and was almost twice as great a year or so ago, although the writer believes that on account of the steadily increasing development of the use of this fuel, these refractory costs will be steadily decreased.

Table 2 shows a comparison of fuel costs for all fuels now used on open-hearth furnaces and it will be seen that natural gas is not only the ideal fuel but is the cheapest.

Pulverized Coal in Stationary Plants

Many engineers who attempted to burn coal in pulverized form obtained unsatisfactory results, and concluded it was "impossible." In many of the earlier trials to burn pulverized coal under boilers the usual method was to install coal-feeding devices of some kind in the furnace as it stood, with the result that the fire bricks melted down and the tubes were plastered with unconsumed carbon, ashes and soot. So destructive were the results

TABLE 2 FUEL COSTS FOR OPEN-HEARTH FURNACES

Kind of fuel	Remarks	Amount per ton steel	Rate cost fuel, dollars	Cost of fuel and labor, dollars	Cost per ton steel, dollars
Natural gas	.....	6000 cu. ft.	0.04 per M	....	0.24
Natural gas	.....	6000 cu. ft.	0.12 per M	....	0.72
Producer gas	Hot metal	510 lb. coal	3.40	3.93	1.00
Producer gas [1]	Cold metal	739 lb. coal	3.40	3.93	1.46
Fuel oil	.....	40 gal.	0.02	....	0.80
Tar [2]	.....	40 gal.	0.025	....	1.00
Pulverized coal	.....	500 lb. coal	3.40	3.90	0.975
Electric power	.....	500 kw-hr.	0.0075	....	3.75

Above includes handling cost.

[1] Atlantic Steel Company, Atlanta, Ga.

[2] Tar is a waste product at some plants and has to be burned.

that those making the tests can hardly be blamed for arriving at the conclusion they did. How close some were to success was not fully realized. Conditions were not ripe. Today results are being obtained that are of sufficient importance to warrant careful investigation and consideration.

For the proper combustion of coal under boilers, there are five main points which must be given serious consideration, otherwise the burning of this fuel will not be a success. These five points are coal fineness, size of combustion chamber, necessary air opening, proper damper regulation, and clean tubes.

Coal Fineness. The pulverized coal should run about 96 per cent through the 100-mesh screen and about 85 per cent through the 200-mesh screen. If it runs below 80 per cent through the 200-mesh screen, particles of carbon will fly through the air inside of the combustion chamber, and as these particles are not completely burned when the gases reach the tubes, they will deposit themselves on the tubes. These heavy particles in the pulverized-coal mixture will sometimes settle on the bottom of the combustion chamber and will soon build up in the shape of stalactites. This accumulation will continue to build until the bottom of the combustion chamber continues to be raised, until it comes in contact with the flame. These built-up particles will then fuse into a solid mass, which, in a very short time, will cause a shut down of the boiler to dig this fused mass out. It is, therefore, necessary, for the successful burning of this pulverized fuel under boilers, to have this coal as finely pulverized as possible.

Size of Combustion Chamber. Before installing, or considering the use of pulverized coal under boilers, a study of the boiler-house installation should first be made, the rating at which the boilers will be operated decided upon, considering any peak load which may develop. The combustion chamber should be designed large enough to take care of the maximum loads which will be developed from the boilers at any time. After this maximum rating has been determined, the combustion chamber is designed, using a cubical capacity equivalent to approximately 50 cu. ft. per lb. of coal burned per min., or approximately 2½ cu. ft. per hp. developed by the boiler. If it is decided to run this boiler at 150 per cent of this rating and the combustion chamber is designed accordingly, the efficiency will not be decreased perceptibly if the boiler is run under this 150 per cent rating, but if over a 150 per cent of the rating is developed serious difficulties will result. More coal and air must be admitted to the boiler to develop the greater rating, and consequently more combustion space is needed; and finally if this combustion space is not available the flames impinge on the brickwork and cut it away very rapidly. Also, combustion is not complete at the time the gases strike the bottom row of tubes and consequently the gases will pass up the stack unburned. Efficiency is then decreased. The size of the combustion chamber should also be so designed that the velocity of the gases should not pass through this combustion chamber at a speed of more than 6 ft. per sec. The mixture of air and coal entering the combustion chamber, as stated above, should be at as low a pressure as is possible to

bring this mixture in in suspension; or, in other words, breathe it in.

Proper Air Openings. The pressure at which the pulverized coal is admitted to the furnace is as low a pressure as can be used to carry this fine coal in suspension, and is about half an ounce pressure at the nozzle. In some installations the coal falls by gravity from the variable-speed screw conveyor, located on the bottom of the pulverized coal bin, into a fan air line which carries it into the furnace and also supplies the necessary air for combustion. Some few openings are placed in the front wall of the boiler to give any additional air which may be needed, and a few may also be placed on the side walls of the boiler to protect the brickwork at times.

In other installations the amount of air necessary to convey the coal into the furnace varies, according to the rate at which the boiler is being operated. The balance of the air to burn the coal properly is admitted through adjustable air openings in the front, sides and bottom of the combustion chamber. These openings are made adjustable and are placed on all sides of the combustion chamber to take care of the various grades of coal which may be used in the boiler plant. By properly observing the combustion in this chamber, by a little experience the fireman knows at exactly what points to give more, or less air needed for combustion.

Damper Regulation. In order to give the proper velocities of gases passing through the combustion chamber, it is necessary to have very accurate damper regulation to take care of the various load conditions which the boiler is to supply. The damper should be so regulated that it will maintain practically a balanced draft inside of the combustion chamber and only a slight vacuum in the first pass, while at the damper itself not more than 0.10 to 0.15 in. is required. If there is more vacuum than this, it pulls the gases through the combustion chamber too fast, causing them to be unburned before reaching the first row of tubes and will then build up very fast on the outside of these tubes. This very small draft needed at the base of the stack will allow us to operate boilers using pulverized coal with stacks of about 30 to 35 ft. in height.

Clean Tubes. In order to get the maximum evaporation from any boiler it is necessary that the tubes be kept clean. They should therefore be blown at least every 6 hours. Once every 24 hours the bottom of the first row of tubes should also be blown as these are the tubes in which the gases come into contact first after leaving the combustion chamber. This material can be blown off easily if the combustion chamber has been properly constructed and if the tubes are blown regularly as needed. If they are not blown regularly this material accumulates very fast and in time will become fused and cannot be blown off.

Another item, which might have been called the sixth point, is the removal of ash which deposits at the bottom of the combustion chamber. This ash should be removed at regular intervals, which intervals will be determined by the amount of ash in the original coal. If the ash is not removed regularly, it will build up until it comes in contact with the flame, when it becomes fused and has to be dug out. But if removed at regular intervals, it can be easily raked out with the ordinary boiler-room ash rake and will not consume more than half an hour per 24 hours, and will not interfere with the operation of the boiler while this is being done.

PULVERIZED COAL VS. STOKERS

The following are some advantages of pulverized coal as a fuel for boilers over stokers:

a Much wider variation in the quality of the coal usable is obtained when burning coal in pulverized form. Practically any and all grades of coal can be burned in this form with economy.

b The ability to take care of peak loads almost instantaneously. In other words, a pulverized-coal burning system is much more flexible than a stoker installation. Its flexibility approaches that of oil or natural gas.

c The amount of coal that can be burned per square foot of grate surface on stokers is limited so that for increased capacity the boiler setting must be spread out to cover more area. When using pulverized coal, this condition does not exist, for proper furnace conditions can be obtained by increasing the height of the boiler setting or the depth of the combustion chamber.

d By throwing a switch the entire firing operation ceases; an advantage in case of accident or emergency.

e Ash is in much better condition to handle. The ash is in the form of a dust or slag depending upon its melting point. This helps to maintain constant furnace temperature as there are no interruptions to firing conditions on account of cleaning fires.

f Pulverized coal is fired dry, containing less than 1 per cent of free moisture, whereas coal burned on stokers may vary anywhere from 1 to 10 per cent, of free moisture as fired.

g Considerably less excess air is necessary for complete combustion. This item is of the utmost importance when making comparisons. Less excess air means less power for furnishing air supply, particularly where forced draft is used. With less excess air the stack losses are less. Lower grades of coal fired on stokers require more excess air as it is quite difficult for the oxygen to get in close contact with the combustible. An air supply sufficient to furnish all the air for combustion should be available, although at times only 50 per cent of the air is necessary to be injected into the furnace with the coal, the balance being supplied by the induction action of the burner or drawn in by the stack draft through the various adjustable openings in front and sides of combustion chamber. The air going into the furnace should be under control to permit close regulation under all conditions of firing.

h With furnace properly proportioned and with properly designed burning equipment smokeless operation may be maintained indefinitely. This is due to complete combustion of all the particles of coal before coming in contact with the cold surface of the tubes of the boiler.

The following few points must be kept in mind for the successful burning of pulverized coal under boilers:

a A boiler furnace using pulverized coal should have as few burners as is possible consistent with good regulation. The burners must be proportioned for the maximum rating of the boilers, and they must be adjustable. Simplicity of design is desirable. It has been found much more desirable to introduce coal into the furnace as far away from the side walls as possible so that the rapid continuous expansion of the gases will not develop high velocities in close contact with the furnace refractories. Furnaces under boilers should be proportioned so that the velocity of the gases should not be excessive, particularly at the smallest cross-sectional area of the furnace. Vertical baffles should replace all horizontal baffles.

b A boiler of any size can be fired successfully with pulverized coal. Various designs and makes of boilers can be readily arranged for pulverized-coal firing, but those containing the smaller percentage of space for the lodgment of ash are preferable.

c Feeders for regulating the flow of pulverized coal to the furnace must be designed so that at all times the variation in quantity will be directly proportional to the speed of the screw and no flooding allowed. The speed of the feeder should be so regulated that operating at its maximum r.p.m. the supply of pulverized coal to the furnace will not exceed the capacity of the furnace. Soot blowers should be installed in settings where pulverized coal is used.

d The equipment for using pulverized coal is standard for any grade of coal so far as handling, preparing and delivering to the furnace is concerned. Only a slight change is necessary in the furnace to take care of coals of very low volatile content, such as anthracite, culm and coke breeze, and increased drying capacity is desirable when lignite coal is used. With stokers this is not the case as the varying quality of coals require different type stokers to obtain highest efficiency.

TEST OF A BOILER USING PULVERIZED COAL

The following is a report of a test made on a 468-hp. boiler using pulverized coal as fuel. This installation is noteworthy not only by reason of the high efficiency obtained, but also because of the fact that it has made clear some of the conditions necessary for the successful operation of boilers utilizing powdered fuel.

When the boiler was first put into operation, a number of undesirable conditions resulted. An insufficient air supply caused high furnace temperature resulting in fusion of the ash particles and a consequent accumulation of slag between the tubes, on the furnace walls and in the ashpit. The removal of the molten slag presented considerable difficulty. It was also found that the combustion chamber was of insufficient size. High gas velocities resulting from insufficient air in the chamber tended toward destruction of the refractory surfaces of the furnace.

A new furnace was therefore designed. The combustion chamber was enlarged and a regulated air supply was provided for by means of a number of auxiliary air openings equipped with dampers. The accumulation of slag in the pit was prevented by raising the point of admission of the fuel into the

furnace. As a result the flame path has been raised above the base of the pit, hence particles of ash dropping from the flame are not fused. The ash, therefore, can be drawn from the pit in the form of a powder and small slugs of slag. Analysis has shown that the ash contains practically no carbon.

Having established satisfactory furnace-operating conditions, a series of efficiency and capacity tests were conducted preliminary to proving the contract guarantees. The brickwork was then given a thorough trial by carrying the boiler at a continuous rating of 180 per cent over a period of several days. On August 12 and 13 a final efficiency test was made. The results are given in Table 3. The boiler is a three-pass water-tube boiler, equipped with a superheater.

At this same plant are other boilers fired by one of the most efficient types of underfeed stokers. A comparison is made between results of above test and tests made on the stoker-fired boilers.

PULVERIZED COAL VS. MECHANICAL STOKERS

Under this heading fuel-preparation costs will first be considered. In the case of powdered coal this can be classed under three general divisions:

a The cost of crushing the coal. This expense is the same for pulverized-coal equipment as for stokers.

b The cost of drying and pulverizing the coal. Although no cost records are available at present, it is estimated that 32 cents per ton will cover this preparation cost on a 200-ton-per-24-hr. plant using bituminous coal containing about 12 per cent moisture.

c The maintenance costs of the drying and pulverizing plant. This unit has not been determined from actual experience; however, it is estimated that 3 cents per ton will cover the maintenance. In stoker practice the maintenance cost per ton of fuel fired is close to 5 cents per ton.

TABLE 3 LOG OF TEST OF A PULVERIZED-FUEL-BURNING STATIONARY BOILER. DATE AUGUST 12–13, 1918

Make of boiler			Edge Moor
Rated hp			468
Heating surface, sq. ft			4685
Time fired or test started			11 15 a.m. 8/12/18
Time fire out or test finished			11 15 a.m. 8/13/18
Duration of test hr			24
	Maximum	Minimum	Average
Temperature of boiler room, deg. fahr.	99	85	93.3
Temperature of feedwater	168	135	157.2
Temperature of steam, deg. fahr	477	427	448.7
Barometer, in. of mercury	29.35	29.20	29.25
Temperature of flue gases, deg. fahr.	515	455	495.3
Average boiler pressure, lb.			167
Atmospheric pressure, lb.			14.4
Temperature of steam, deg. fahr			373.8
Superheat, deg. fahr			74.99
Safety valve set for, lb.			175
Fuel fired per hr., lb.			1,990.6
Total fuel, lb.			47,775
Total water, lb.			393,168
Water apparently evaporated per hr., lb.			16,393
Water apparently evaporated per lb. of coal, lb.			8.23
Factor of evaporation			1.1502
Water evaporated from and at 212 deg. fahr. per lb. of coal, lb.			9.47
	Maximum	Minimum	Average
Carbon dioxide (CO_2) per cent	15.4	12.2	13.85
Oxygen (O) per cent	5.6	3.2	4.38
Carbon monoxide (CO)			None
Fuel used			Bituminous screenings
Fuel analysis	No. 1	No. 2	No. 3	Average
Amount of coal represented by each sample, lb.	19,775	20,000	80,000	..
Per cent of total	41.3	41.1	16.9	..
Moisture, per cent	10.3	11.0	9.7	10.49
Volatile, per cent	33.81	36.96	38.77	35.96
Fixed carbon, per cent	50.43	49.13	48.29	49.53
Ash, per cent	14.36	13.91	12.94	13.93
Sulphur, per cent	1.90	2.06	2.12	2.04
B.t.u. as received	10,600	10,763	11,263	10,779
B.t.u. dry	11,817	12,093	12,473	12,045
Vacuum in burner, in.				0.000
Vacuum under primary arch, in.				0.000
Vacuum in combustion chamber, in.				0.000
Vacuum in first pass, in.				0.000
Vacuum in second pass, in.				0.0057
Vacuum in breeching, in.				0.09
Feeder speed, r.p.m.			(No. 1), 53.6; (No. 2), 50.7	
Coal per revolution of screw, lb.				0.318
Accumulation of slag on tubes				None
Flues blown during test				5 times
Operation of furnace				Very satisfactory
Pulsation				None
Condition of smoke				Light
Heat effect on brick				None
Backlash of flame in burner				None
Pounds of steam per hr. from and at 212 deg. fahr.				18,842.6
Horsepower				546.2
Per cent of rating				116.7
Boiler efficiency, per cent				85.22
Memoranda—Fuel-preparation deduction:[1]				
Coal used in drier, lb.				1,140
Motor operation, kw-hr				449.3
Coal equivalent at 3 lb. per kw-hr., lb				1,348
Total deduction, lb.				2,488
Resulting net efficiency, per cent				81.1

[1] No deduction made for stand-by losses in drier.

Summarizing the above facts it is evident that, with fuel at $5 per ton, the gross efficiency shown by the pulverized-fuel boilers will have to exceed that shown by the mechanical-stoker-fired boilers by 6 per cent in order to offset coal-preparation costs. A 6 per cent deduction from a gross efficiency of 85.22 per cent results in a net efficiency of 79.22 per cent for the powdered-coal burner. In stoker practice the maximum attainable gross efficiency at any of our plants has been 80.54 per cent. Deducting the 2.5 per cent for auxiliary uses, the resulting net efficiency is 78.04 per cent, which is lower by 1.18 per cent than the figure obtained in pulverized-fuel practice.

Other advantages resulting from the use of pulverized fuel are summarized herewith:

a Continuous boiler operation at a uniform rating as well as a constant efficiency is made possible. At no time is there a loss in capacity due to the clinkering of coal on the grates or the cleaning of fires, as is the case in stoker practice.

b Heavy overloads can be taken on or dropped off in a very brief time through adjustment of the coal feeders and the furnace drafts.

c From 97 to 98 per cent of the combustible in the coal is utilized, regardless of the quality of the fuel.

d The ash-handling costs are reduced to a minimum due to the reduced volume.

e The banking conditions when operating with pulverized coal are somewhat different from those obtained in stoker practice. By stopping the fuel supply and closing up all dampers and auxiliary air inlets a boiler can be held up to pressure for about 10 hr. The furnace brickwork having been heated to incandescence during operation gives off a radiant heat which is absorbed by the boiler rather than being sent out through the stack. The case of controlling the fuel, feed and drafts, the ability to take on heavy overloads in a brief time, the thorough combustion of the coal and the uniform high efficiency obtainable under normal operating make pulverized coal a most satisfactory form of fuel for central station uses.

The full story of maintenance expense is only partly known, however, but all indications are that no unusual difficulties will be met. The cost of fuel preparation and labor for operating a boiler room fully equipped with pulverized-coal-burning boilers will be a question for the engineer to decide for himself according to his particular conditions. If properly installed with respect to capacity of storage, size of drier and pulverizers, and on a sufficient number of boilers to properly and fully employ the minimum number of men, the pulverized-fuel installation will undoubtedly be more advantageous. The main item that must be borne in mind by engineers is that the case with which a high efficiency is obtained and the constant nature of that efficiency, as compared to the lack of constancy of efficiency in a stoker-fired boiler, unless very closely supervised, is the one factor which justifies the burning of pulverized fuel. There is no doubt that with a well-equipped plant burning pulverized fuel, having all the necessary recording and indicating instruments to guide the operators in maintaining the proper conditions, a lower cost of generating steam will be possible than has heretofore been the case in any type of equipment.

Pulverized Coal for Stationary Boilers

By FRED'K A. SCHEFFLER,[1] NEW YORK, N. Y., AND H. G. BARNHURST,[2] ALLENTOWN, PA.

It is the purpose of this paper to present those facts which the authors believe indicate the coming general adoption of pulverized coal as a fuel for boilers. Since stoker firing is the most efficient method when solid fuels are used, a comparison of stoker and pulverized-fuel plants is given, with particular reference to reliability, cost, adaptability and efficiency. The cost of pulverizing coal and the cost of stoker operation are discussed in detail and tables given showing results of tests on pulverized-fuel plants and data regarding boiler installations using pulverized coal as a fuel.

ALTHOUGH a very great interest has been aroused throughout this country and abroad in the adaptation of pulverized coal to boiler furnaces, it is remarkable how little is known, in a practical way, of what is actually being done, how it is accomplished, and what results have been obtained. The purpose of this paper is therefore to set forth the facts which indicate the coming general adoption of pulverized coal as a fuel for boilers, the discussion being presented in the form of a comparison with stoker firing—the most efficient method in general use for burning solid fuel under boilers. It is hoped that the data and illustrations presented will prove of interest and will call forth discussion which will serve to develop further this study of the best method of reducing power-operating costs.

The ultimate adoption of a new method depends entirely on its overall commercial efficiency. In the generation of power, overall efficiency may be considered as composed of the following factors: reliability, cost and adaptability. A method may acquire a wide field if it shows improvement in any one or two of these points. Improvement in all three points leads to the general superseding of other methods.

Reliability. This factor depends on two items: apparatus for preparing and presenting the fuel for combustion, and continuity of operation of the furnace itself. In a stoker installation the first of these includes the stoker itself. Neglecting the inherent defects of any system that presents a metal mechanism to the action of high temperatures, it may be admitted that the stoker system is satisfactorily reliable, with respect to its apparatus, for preparing and presenting the coal for combustion.

The corresponding mechanisms for pulverized fuel are equally reliable. This fact is proved by their widespread use for years in the cement industry and more recently in an ever-increasing variety of industries. It should be recognized that these mechanisms are not innovations, but are the result of years of development under operating conditions. Proper design of equipment by engineers of standing who are specialists in this line has made negligible the danger of dust explosions, the occasional occurrences of which in years past have furnished ammunition to the opponents of pulverized fuel.

The second condition for reliability is the continuity of operation of the furnace. Here again there will be found an apparent balance between stoker and pulverized-fuel installations. The advantage, however, lies with pulverized fuel, and for several reasons. The mechanism is altogether outside the furnace, hence cleaning and adjustment and the making of the few repairs required need not interrupt the operation of the boiler. In case of sudden necessity the fire may be ignited and quickly brought to full intensity, or it may be extinguished almost instantly. The greater uniformity of flame and temperature is also conducive to longer life of the furnace lining in a properly designed furnace, and to a minimum variation in furnace efficiency. Finally, the pulverized-fuel installation relieves the power plant from dependence upon the availability of a certain grade of coal. Stokers will not handle all grades of coal.

Presented at the Spring Meeting, Detroit, Mich., June 16 to 19, 1919, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. The paper is here printed in abstract form and is subject to revision. Copies of the complete paper may be obtained at a nominal cost.

[1] Manager Pulverized Fuel Dept., Fuller Engineering Co.

[2] Chief Engineer, Fuller Engineering Co.

Cost. This second factor refers to the cost per B.t.u. delivered to the boiler. The various items entering into this cost by the stoker system comprise power, repairs and maintenance, labor, interest on investment, depreciation, insurance and taxes.

With pulverized-coal equipment the cost of fuel for the drier should be added to the preceding items, as it is clearly cheaper to remove the excess moisture content from the coal in a drier, from which the gases leave at very low temperature, than in the furnace itself, where the evaporation of the moisture damps the fire, increases the content of inert gases and carries off a very perceptible amount of heat.

Returning to the balanced cost items, it appears that these show a saving in favor of pulverized fuel in a large power plant and for the stoker in a small power plant. The figures in question are discussed further on in detail. It should be noted that when central pulverizing plants are built they will relieve small power plants of the necessity for maintaining pulverizing equipment and will make pulverized fuel considerably cheaper than stoker-fed fuel, regardless of the size of installation. This feature is already being carried out successfully.

The final item of the cost, namely, furnace efficiency, which governs all the others, results in all respects to the advantage of pulverized fuel for the following reasons:

First: The fuel enters the combustion chamber in a finely divided state, being introduced with air at low pressure, and is approximately perfectly mixed with the air for theoretically perfect combustion. Therefore no excess air is required for complete combustion. Should it be desired for other reasons to introduce excess air with pulverized fuel, it can be done in exact amounts, evenly distributed, without affecting the uniform nature of the flame and flue gases. This uniformity, which cannot be obtained in either grate or stoker installations, means maximum efficiency in all parts of the furnace and a maximum rate of heat transference to the boiler throughout its exposed area. It also means that flue-gas analysis gives an accurate determination of conditions in the furnace, and that control of coal delivered and air supply can be adjusted with great accuracy.

Second: In pulverized form all of the combustible is burned, a consummation certainly impossible in lump-coal firing by either hand or stoker. It is not unusual to find 20 to 30 per cent of carbon in ash refuse from grate- or stoker-fired boilers.

Third: With pulverized fuel there are no stand-by losses, either with change of load or when shutting down, such as banked fires, etc.

Fourth: With properly designed pulverized-fuel apparatus nothing of a mechanical nature takes place in the furnace. In stoker and grate firing not only is the mixing with the air done in the furnace, but the presentation of fresh surfaces of combustible to the air supply must take place by the removal of the ash and its discharge through the grate bars, or the pressure must be great enough to force the air supply through the ash bed.

Adaptability. The third factor of overall efficiency is adaptability. Pulverized fuel is here preëminent. The primary feature is the possibility of burning all grades of fuel without affecting the efficiency of the furnace. To burn anthracite and very low grades of fuel requires a furnace allowing a return flow of the flame past the incoming flame, to heat up the incoming fuel, and in a furnace of this type fuel containing over 50 per cent ash has been burned with high efficiency.

The flexibility in the use of pulverized fuel is perfect, and the fire may be instantly adjusted to suit any condition of overload or lower load, including the cutting in and out of the boilers. The paramount importance of this feature and the utter impossibility of approaching it with stoker or grate firing is readily evident. Furthermore, the operation and the determination of conditions for complete combustion may be made automatic, the result being a smokeless and sootless boiler plant, which is essential in modern cities.

Furnace Design. The primary requisite for good results is to maintain low velocities in the furnace in order to avoid damage to the linings and their erosion. A furnace cubical in shape usually gives the most satisfactory results. The burners should inject the coal under low pressure and should permit of varying the density of the mixture in the burner itself. Their location and number will depend upon the size of the boiler and rating required, and also may be varied to suit the grade of fuel. High boiler ratings such as are used in modern boiler practice can be obtained when desired, and such overratings should be predetermined and the furnace volume designed accordingly.

In Table 1 will be found an itemized statement of the costs of pulverizing coal, and in later paragraphs some statements as to the cost of stoker operation for purposes of comparison. Table 2 gives reports of preliminary tests made on some of the pulverized-fuel installations now in operation. A third table in the complete paper gives particulars regarding 19 installations since August 1916, comprising 96 boilers of various types and sizes ranging from 100 to 600 hp. and aggregating 25,000 hp. in capacity. While these do not show the maximum efficiency to be expected with the further development of the art, they nevertheless indicate that the inherent difficulties have been solved and that at the present moment pulverized fuel is in a position to compete advantageously with any other method of burning solid fuel under boilers.

TABLE 1 COST OF DELIVERING PULVERIZED FUEL TO BOILERS

	100-ton plant, dollars per net ton	1000-ton plant, dollars per net ton
Power at ¾ cent per kw-hr. and 17 kw-hr. per net ton	$0.1275	$0.1275
Labor at 40 cents per hr.	0.14	0.04
Drier coal at $5 per net ton delivered	0.06	0.06
Repairs	0.07	0.07
Total actual cost of pulverizing per net ton	$0.3975	$0.2975
Interest at 6 per cent	0.105	0.039
Depreciation	0.12	0.04
Taxes and insurance	0.035	0.013
Total cost per net ton	$0.6575	$0.3895

Comparison on an Efficiency Basis

One of the most prominent engineers in this country, a member of the Society, has stated that the combined boiler and furnace efficiency by the month, day in and day out, of a modern stoker-fired power plant with the best average plant operation is not better than from 63 to 65 per cent, although a carefully conducted test on one boiler and furnace might show during several hours' run 75 per cent efficiency. This statement has been confirmed by other engineers. The results with pulverized fuel, however, would be totally different. There is no apparent reason why a combined furnace and boiler efficiency of 75 per cent, and even higher, could not be maintained throughout the year, as the operation of the plant would be practically equivalent to that of a fuel-oil installation, in which stand-by losses, banked fires, etc., are almost entirely eliminated. Unquestionably there should be a saving, under these circumstances, of 12 to 15 per cent of the total coal consumption in favor of pulverized coal, and this reduction, on a basis of even a 2000-boiler-hp. plant, will show a very fair return on the investment, neglecting the fact that a lower-grade and cheaper coal could be used.

Cost of Pulverizing Coal

The cost of pulverizing the coal is of prime importance, as low costs are essential for success and are achieved when the quantity used per day of 24 hr. exceeds 100 tons. The cost of pulverizing is made up of a number of items, namely, power, repairs, coal for drying, labor, interest, depreciation, taxes and insurance.

Power. The power required in an up-to-date pulverized coal plant is from 12 to 13 kw-hr. per net ton of coal crushed, dried and pulverized. The additional power required for transferring the coal to the point of use and feeding it to the boilers will vary considerably, depending upon the distance transported, the size and number of the boilers, and the conditions under which they operate. The power required for this latter purpose varies between 4 and 6 kw-hr. per net ton, so that the total power for the entire process from the track and storage delivered to the boilers is 17 or 18 kw-hr. per net ton. In the following paragraphs the cost of power has been assumed at ¾ cent per kw-hr.

Repairs. The item of repairs, including material, labor and general upkeep of the plant or maintenance, for the entire pulverizing plant and burning equipment will vary from 7 to 10 cents per net ton of coal handled. The figures depend upon local conditions and the size and general arrangement of the entire installation.

Coal for Drying. This item depends directly upon the percentage of moisture and upon the price of coal. Ordinarily only from 1 to 1¼ per cent of the total amount of coal used is required for drying. Assuming coal to have an average of 7 per cent moisture as received and the cost to be $2.50 per net ton, the cost per net ton of drying the coal will be 3 cents. At $5 per net ton the cost of the drier coal will be 6 cents.

Labor. This item is the greatest variable in connection with the pulverizing of coal, due to the increased output that can be obtained in larger plants per man employed. It is also subject to local rates of wages. For example, assuming labor at 40 cents per hour, a plant of 100 tons daily capacity, properly designed

TABLE 2 REPORT OF PRELIMINARY TESTS MADE ON PULVERIZED-FUEL PLANTS

Date of test	Location of plant	Duration, hr.	Coal used	Efficiency maintained, per cent	B.t.u. per lb. of coal as fired	Ash, per cent	Rating, per cent
April 16, 1917	Seattle, Wash.	14.5	Renton buckwheat	77	10,000	11.60	122
Dec. 4, 1917	Chanute, Kan.	5	Kansas bituminous	72	11,996	17.7	125
Dec. 12, 1917	Chanute, Kan.	5	Kansas bituminous	83.94	12,500	18.25	125
Jan. 28, 1918	Chanute, Kan.	(25 days)	Kansas bituminous	78.1	11,435	....	100
April 26, 1918	Parsons, Kan.	6	Kansas bituminous	80.3	12,900	17.49	...
April 28, 1918	Parsons, Kan.	6	Kansas bituminous	80.9	12,289	17.49	130.8
June 14, 1918	Milwaukee, Wis.	12	Illinois and Indiana screenings	83.3	10,897	15.89	117.7
Nov. 5, 1918	Lykens, Pa.	10	Lykens No. 3 buckwheat anthracite	84.2	12,530	16.92	135
Nov. 15, 1918	Lykens, Pa.	5	Lykens slush buckwheat anthracite	81.2	13,653	11.09	142
Nov. 22, 1918	Lykens, Pa.	5	Lykens slush buckwheat anthracite	85	12,753	18.04	146
Nov. 23, 1918	Lykens, Pa.	5	No. 3 buckwheat anthracite	72.7	12,530	16.91	115
Dec. 2, 1918	Lykens, Pa.	5	Lytle slush anthracite	75.3	15,420	23.92	188
Feb. 1, 1919	Seattle, Wash.	24	Issaquah screenings	78.95	11,660	14.31	126
Feb. 2, 1919	Lykens, Pa.	4	No. 3 buckwheat anthracite	78.9	13,067	14.02	177
April 7, 1919	Vancouver, B. C.	4	Nanaimo slack	83.3	9,364	28.4	125
April 17, 1919	Vancouver, B. C.	5	Nanaimo slack	77.1	10,050	24.3	160
Feb. 3, 1919	Lykens, Pa.	5.5	No. 3 buckwheat anthracite	78.9	12,530	14.00	...
Sept. 24, 1918	Verde, Ariz.	(6 days)	Gallup, New Mexico	79.5	10,680	14.31	135

and equipped, will require approximately 34 labor hours to prepare the fuel and deliver it to the conveyors, whereas in a plant having a daily capacity of 1000 tons, approximately 115 labor hours are required. Therefore the labor cost would be 14 cents per net ton in a 100-ton plant, only 4 cents per net ton in a 1000-ton plant, and as low as 2½ cents per net ton in a plant of 5000 tons daily capacity.

Interest. The interest item is based on 6 per cent of the entire investment, and the cost of the pulverized-coal plant and burning equipment will of course vary considerably with the conditions under which the plant is installed. Roughly speaking, however, the actual investment will vary from $12.80 per kw. output in a 5000-kw. plant down to $4.80 per kw. in a 50,000-kw. plant and $4.12 in a 100,000-kw. plant (assuming a turbo-generator water rate of 16 lb. and continuous boiler and furnace efficiency of 75 per cent).

All these figures in relation to cost are based on the present high prices. The investment required for a 5000-kw. plant using 100 tons of pulverized coal daily is approximately $64,000 and for a 50,000-kw. plant using 1000 tons of pulverized coal daily, approximately $240,000, so that, on a basis of 6 per cent and allowing for 365 days' continuous operation, the interest item will vary from 10½ cents per net ton in a 100-ton plant down to 3.9 cents per ton in a 1000-ton plant.

Depreciation. Depreciation in a coal-pulverizing plant is usually calculated as follows: The life of the building is considered as 40 years, of the coal driers as 15 years and of the remainder of the equipment as 20 years. With a 100-ton pulverized-coal plant and burning equipment the depreciation item will be approximately 12 cents per net ton, and in a plant of 1000 tons daily capacity it will be approximately 4 cents per net ton.

Taxes and Insurance. Taxes and insurance are based on 2 per cent of the entire investment, and for a 100-ton plant this item is approximately 3½ cents per ton and for a 1000-ton plant, 1.3 cents per ton. Summarizing, the foregoing results show that the total cost of pulverizing and delivering pulverized coal to boilers is approximately as given in Table 1. The cost of the pulverizing equipment complete compares favorably with the stoker equipment when everything, such as coal- and ash-conveying machinery, etc., is taken into consideration, and in large plants it is considerably less.

Cost of Stoker Operation

The equipment required for a first-class stoker installation must necessarily be taken into consideration when making a comparison of the costs of the different installations. The cost of pulverizing is an item of expense which must be included with the cost of the fuel, and since it includes the complete handling of the coal, the expense of crushing, handling, power, repairs, maintenance, interest, taxes and insurance covering the stoker equipment must also be considered when making comparisons.

Stoker installations and operation are expensive and the investment is as great, if not greater, than that required for a pulverizing equipment in plants of 10,000 kw. and upward. For example, in a plant using 1000 tons in 24 hours the cost of operation will be approximately as follows:

Power for stoker, 2 per cent of the total boiler hp. developed..	$180.00
Power for fans, 2 per cent of the boiler hp. developed.....	180.00
Coal handling, 100 kw. at ¾ cent per kw-hr.....	18.00
Labor for coal handling, 2 men per shift and 3 shifts at 40 cents per hour	19.20
Repairs for stokers at 30 cents per boiler hp. per annum....	17.50
Repairs for coal-handling equipment.....	10.00
	$424.70
Total cost per net ton.....$0.425	

To this must also be added the cost of fuel used to heat the moisture in the coal, interest, depreciation, insurance and taxes, showing that even on a basis of equal efficiency the cost of operating a pulverized-coal equipment is considerably less than the cost of operating an equivalent stoker installation. It should be stated that the figures just given are based on present average results in both cases.

DISCUSSION AT FUEL SESSION OF SPRING MEETING

THE Fuel Session of the Spring Meeting was held on the morning of Thursday, June 19, Vice-President John A. Stevens officiating as chairman. Three papers were presented at this session: namely, Pulverized Coal as a Fuel, by N. C. Harrison; Pulverized Coal for Stationary Boilers, by Fred'k A. Scheffler and H. G. Barnhurst; and Economy of Certain Arizona Steam-Electric Power Plants Using Oil Fuel, by C. R. Weymouth. The latter paper, which was presented by title only, was published in MECHANICAL ENGINEERING for June, p. 523; the two papers on pulverized coal, which were jointly discussed, appear elsewhere in this issue. Extensive extracts from the discussions of these papers immediately follow.

Discussion of Papers on Pulverized Coal

THOMAS A. MARSH[1] (written). The writer would preface his discussion by the statement that the general proposition of taking raw coal with all of its by-products and preparing it to the most expensive size (pulverized) and then burning still raw coal and losing the by-products, appears to be a move very much in the wrong direction. Pulverized coal has a field, no doubt; for instance, such fuels as lignites as cannot be burned on stokers. This field is limited, however, for chain grates are now developed to burn lignites containing 30 to 35 per cent moisture, which embraces practically all but those of the North Dakota field.

Pulverized fuel is adaptable to certain processes as the cement process and certain metallurgical processes. In substantiation of its adaptability for steam boilers, however, the paper by Messrs. Scheffler and Barnhurst represents pulverized fuel at its best, hints at not a drawback or trouble, submits tests of four or five hours' duration and evidently not made under the A. S. M. E. code, and contrasts stokers of the most expensive type to operate as to power to drive and as to power for fans. If it is necessary to resort to such extremities to make a comparable showing for pulverized fuel, it cannot be said that it is on a competitive basis with modern automatic stokers and furnaces.

The following discussion and questions are submitted in the hope that the full answers thereto will provide facts on which to base conclusions in accordance with the Society's past standards.

Reliability. Under the item of "Reliability" in the above-mentioned paper it is stated unqualifiedly that the mechanisms for pulverizing fuel are equally reliable with those for crushing coal for stokers. The extra equipment necessary for this exceedingly elaborate preparation of the fuel is another link to the mechanism (and a high-speed one at that), and I think no engineer will agree that the combination of a crusher system and a pulverizing system is as reliable as a stone crusher alone. Even if this complex system were equally reliable as a crusher, which it is not, the station dependent on pulverized fuel would suffer shutdowns unless the crusher and pulverizer equipment were duplicated. The writer understands that cement plants are usually equipped with duplicate pulverizing systems. This will all have a bearing on investment charges.

Further, it is stated in the paper that all grades of coal can be used. There are stokers which have limitations only on anthracite or coke breeze and in this connection the question arises as to whether a pulverized-coal furnace and burner designed for, say, bituminous 35 per cent volatile will burn anthracite or coke breeze. I ask this because in one of our other technical societies it is a matter of recent record that for burning low-grade

[1] Chief Engineer, Green Engineering Co., Chicago, Ill. Mem. Am.Soc.M.E.

anthracite or coke breeze in pulverized form, reversal of the flame is necessary, a firing method not suitable for the richer bituminous coals. It was also brought out that with coke breeze or anthracite culm the fire was unresponsive and the load had to be varied to suit the fire rather than the fire to suit the boiler load. What occurs when a rich high-grade fuel is used in a furnace and burner designed for low-grade fuels?

Adaptability. Under this heading the authors state that the primary feature is the possibility of burning all grades of fuel without affecting the efficiency of the furnace. In order for this to be true, it is necessary to burn the 50 per cent ash coal with no more excess air than the 3 per cent ash coal and suffer no more ashpit loss in the former case than in the latter. The writer therefore specifically asks if the 50 per cent ash coal requires in practice no more air than the 3 per cent ash coal. When 50 per cent ash coal is used the sensible heat of this amount of refuse leaving the furnace chamber is in itself an item which will affect the efficiency of the furnace. Can efficiencies be independent of these items? The tests show wide variation in efficiencies. What causes these wide variations?

Chain grates are burning coals containing 35 per cent ash and producing some excellent results, and have been for years. It would be desirable along with this statement by the authors regarding high-ash fuels for them to submit figures of tests with over 28.4 per cent ash, which is rather a low percentage as compared with chain-grate practice with western fuels.

As to flexibility with pulverized coal, the writer has seen cases where the furnace became unresponsive when forced. There is certainly no evidence in the paper to indicate that the pulverized-fuel burner is quickly responsive over a wide range of loads; in fact, the evidence is much to the contrary, for of all the tests referred to, the maximum overload indicated is 188 per cent, which is not considered a high overload in modern specifications and practice.

Furnace Design. Under this heading the tests of Table 2 are referred to. Tests of four or five hours' duration should not be included in an A. S. M. E. paper. Efficiencies of 70 to 80 per cent are shown here. Starting and stopping conditions, surging of water in the boiler and other items are so uncertain as to make these short tests absolutely unreliable. Under similar conditions, tests of 100 per cent efficiency and even higher are frequently made.

To be more specific, the writer would inquire if in the test of April 16, 1917, at Seattle, the heating value of the coal was determined by a calorimeter or was it assumed. The even figure of 10,000 simply suggests estimated figures.

What great difference brought about the marked increase in efficiency between the December 4 and December 12, 1917, tests at Chanute, Kan.? This wide difference is inconsistent with the statement of uniform efficiencies, regardless of operatives, coal or other items.

On the January 28, 1918, test at Chanute, Kan., of 25 days' duration, were the water and coal weighed? Did the boiler operate this long without the blow-off being opened, or if the boiler was blown down, how was the blow-off discharge measured?

Tests of April 26 and 28 at Parsons, Kan. Some tests were made at this plant simply by measuring the coal in a spiral conveyor. Was this done in this instance or were the coal and water properly weighed? The writer has a record of other tests made at this plant, as follows:

Horsepower Developed	Combined Boiler and Furnace Efficiency Per cent.
186	53.9
194	73.5
230	67.8
247	67.4
506	61
356	59.0
230.5	71.5

These results indicate the possibility of low efficiencies on tests with pulverized fuel. What, then, may we expect in daily operation? Why should we pick only favorable tests for comparative figures?

On the test of April 26, should not the percentage of rating be given?

The writer is surprised at the high calorific value of the slush anthracite in all tests reported, as it has the highest heat value of any coal in the tabulation. We should not confuse this with low-grade anthracite, which contains less than 9000 B.t.u. The fuel mentioned in the test of December 2, 1918, is evidently incorrect, as it is difficult to imagine a coal containing 23.92 per cent ash and 15,420 B.t.u. This discrepancy is concurrent with the highest-rating test recorded, casting more or less doubt on the entire test.

The complete data of temperatures, draft and CO_2, together with methods of measuring fuel and water, should be given for these tests.

Referring to the statement that a modern stoker-fired power plant with the best average plant operation obtains an efficiency of not better than 63 to 65 per cent, while carefully conducted tests show 75 per cent efficiency, the writer suggests that the authority for this statement be mentioned so that full credit can be given. This may be true with some types of stokers not completely automatic but dependent largely on the firemen's skill. With the chain-grate type, however, it is far from true, in fact the chain-grate plant operates within 2 or 3 per cent of the test figures, and test figures with modern chain-grate furnaces run frequently in excess of 75 per cent net efficiency. It has always been a feature of chain-grate performance that daily operating results approach very closely to maximum test efficiencies with no deductions to be made for fans or other auxiliaries. The fuel costs for modern chain-grate power stations may be adduced to confirm this fact.

The authors have selected for their comparison those types of stokers with which it is most difficult to get high operating efficiencies, whereas if the comparison were made with completely automatic stokers such as chain grates, the statement made of the operating advantage becomes void, as chain grates are evidently more capable of reproducing test results in daily operation than the pulverized fuel furnace.

Cost of Pulverizing Coal. Under the item of Drier Fuel the writer notes that all costs are based on only 7 per cent moisture and yet many of the fuels mentioned in the tests contain more than 7 per cent. Comparatively few fuels have as low as 7 per cent moisture, particularly west of Pittsburgh. The figures run from 10 to 40 per cent in the western section of the country, figures of 15 per cent predominating. The writer suggests therefore that the drying coal cost should be doubled.

Interest. As mentioned earlier, the pulverizing equipment should be duplicated to prevent shutdowns, which would, of course, raise the equipment's interest charge. There are some uncertainties regarding the cost of this equipment, as some of the plants mentioned are reported to have cost several times the figures quoted in the paper. The writer would therefore safeguard this figure by making it at least three times that used by the authors.

Depreciation. In figuring depreciation, everything should be limited to 10 years, inasmuch as we have all seen three or four complete changes in power-plant equipment in the last 30 years and are likely to see the same in the next 30 years. To figure that the fuel-pulverizing building has a useful life of 40 years is making a pretty strong effort to show up pulverized fuel in a favorable light.

The writer would therefore recalculate Table 1 as given on the following page.

Cost of Stoker Operation. In making this comparison, the authors have again selected those types of stokers which show highest operating costs and cause the pulverized-fuel installation to benefit by contrast.

The power to drive some types of stokers may be as high as 2 per cent. Chain grates require but 1/10 of 1 per cent. Power for fans with those types of stokers requiring fans may be 2 per cent of the power developed. Chain grates have no fans, so this item is eliminated. Coal handling would seem to be an item which would cancel out, as it should cost no more to deliver coal to the stoker hoppers than to the pulverizer. However, accepting these

TABLE 1 COST OF DELIVERING PULVERIZED FUEL TO BOILER

	100-ton plant, dollars per net ton	1,000-ton plant, dollars per net ton
Power at ¾ cent per kw-hr. and 17 kw-hr. per ton	0.1275	0.1275
Labor at 50 cents per hour (40 cents too low)	0.175	0.05
Drier coal at $5 ton delivered (15% H_2O)	0.12	0.12
Repairs (no data—accept authors')	0.07	0.07
Total cost of pulverizing per net ton[1]	$0.4925	$0.3675
Interest at 6 per cent. (Triple the investment)	0.315	0.117
Depreciation (10-yr. basis); Multiply authors' figures by 3	0.36	0.12
Taxes and insurance (no data—accept authors' figures)	0.035	0.013
	$1.2025	$0.6175

[1]In existing plants of 500 to 600 tons daily capacity this figure is reported to actually be $1 or more per ton, indicating that in actual practice and operation many incidental items of cost enter which are not shown in a theoretical estimate.

figures on the authors' basis, we have as follows per 1000 tons of coal:

Power for stokers, 1 hp. per 1000 developed; chain-grate practice, 20 cents per 1000 lb. of steam	$ 4.00
Power for fans, standard chain-grate practice	0.0
Coal-handling power (accept authors' figures)	18.00
Labor for coal handling (accept authors' figures)	19.20
Repairs for stokers (accept authors' figures)	17.50
Repairs for coal-handling equipment (accept authors' figures)	10.00
	$68.70
Total cost per net ton	$0.0687

We have, therefore, an additional cost of from 55 cents to $1.13 per ton against the pulverized-fuel plant, a figure that cannot be made up by increased efficiency, for it must be realized that many stoker installations have given performances within 5 per cent of the highest theoretically possible.

Now as to some of the items not mentioned by Messrs, Scheffler and Barnhurst in their paper.

Fine Ash. The writer understands that from 60 to 80 per cent of the ash carries over to lodge in tubes and combustion chambers, but mostly goes out of the chimney to scatter over the surrounding country. This may by comparison not be objectionable in a cement mill or in some of the localities mentioned in the list of installations, but it is evident that if the Commonwealth Edison Company of Chicago were to scatter fine ash from the 5000 or more tons of coal they burn daily, say 600 to 800 tons of ash, it would create a condition compared to which the worst smoke fog would seem like a paradise.

Slag. Some installations have encountered trouble due to the fine ash slagging in the tubes. The writer would inquire how prevalent this is, how it is overcome or prevented and what influence high boiler ratings seem to exert on it.

The refuse from pulverized-fuel firing contains some combustible. It has been reported that the slag containing this combustible causes damage to ashpits. Is this a serious item of maintenance?

It is reported that pulverized fuel if stored will pack and become difficult to handle. Where the container is jarred or vibrated this action is reported to increase. How serious is this action? Does it interfere with the use of stored powdered coal? Does it preclude its use on shipboard?

Turning now to Mr. Harrison's paper, the coals he states as most suitable seem to have (*a*) less than 10 per cent ash, (*b*) volatile 30 to 40 per cent, (*c*) low sulphur, and (*d*) high melting point of ash. This, of course, means a very choice bituminous coal. Such fuel commands a high price in any market, much higher per 1000 B.t.u. than the high-sulphur, high-ash fuels frequently competing. For instance, there are in Illinois and Indiana coals containing 18 to 20 per cent ash, 3 per cent volatile, 6 to 8 per cent sulphur, with the fusion point of ash at 1900 deg. The writer would inquire as to whether in the present state of the art this fuel could be commercially used to develop, say, 150 per cent rating from a boiler by means of pulverization.

It seems to be a prevalent opinion that lignites cannot be burned on stokers. The writer would rectify this at once. Lignites and sub-bituminous coals are being burned and producing high efficiencies and capacities. The following results of a few tests will substantiate this statement:

Fuel	Colo. Lig.	Tex. Lig.	Mont. Sub-Bit.	Mont. Sub-Bit.	Mont. Sub-Bit.	Mont. Sub-Bit.
Moisture, per cent	23.73	29.93	20.73	15.28	15.27	20.52
Volatile, per cent	35.25	30.96	33.44	37.56	41.24	31.23
Fixed carbon, per cent	33.23	25.45	32.50	38.07	30.91	39.00
Ash, per cent	7.79	11.66	13.28	15.09	12.58	9.25
B. t. u. (comm.)	8511	7124	8772	9118	9553	9096
B. t. u. (dry)	11116	10314	11073	10763	11275	11444
Type of stoker	Green	Green	Green	Green	Green	Green
Type of boiler	B & W	B & W	B & W	B & W	B & W	B & W
Coal per sq. ft. per hr., lb.	28	32	28.91	38.06	30.46	35.31
Furnace draft, in.	0.232	0.32	0.167	0.221	0.17	0.196
CO_2 at damper, per cent	12	11.81	10.36	12.97	11.77	12.62
Per cent. rating developed	128	.....	145.8	209.1	181.5	195.09
Combined efficiency, per cent	69.7	69	72	75.6	77.3	78.04

The ability to burn these coals is a development of the last few years, and has opened up a wonderful fuel field to chain grates. Some of these fuels contain as high as 30 per cent moisture, in which case the drying cost when pulverized fuel is used would be 4 2/7 times those given in Table 1 and would make it necessary for the pulverized-fuel installation to obtain somewhere in the neighborhood of 100 per cent efficiency to be on a competitive basis.

Moreover, these fuels do not at this time command a price anywhere near $5 per ton, so that the cost of drying and pulverizing represents probably about 25 per cent of the fuel cost, a figure not to be regained by increased efficiency.

Reference is made to the use of low-grade refuse around the mines, as at Lykens, Pa. Mr. Sheffler and Mr. Barnhurst also refer to this same fact in their paper. The coals they mention, however, have calorific values not only far beyond the average idea of culm piles (12,500 to 15,400 B.t.u.), but are good enough to be used to advertise the coal. Certainly no western fuels and few mid-western fuels will equal these supposedly refuse coals.

It should be understood that when a chain-grate engineer refers to low-grade coal, he certainly has in mind fuel containing less than 9000 B.t.u., dry basis. No such fuels seem to be discussed even as refuse fuels in pulverized-fuel practice.

Mr. Harrison bases his costs of pulverizing on pre-war labor prices (30 cents per hour for millers, 20 cents for firemen and common labor), war coal prices (which is not consistent with 20-cent labor), and 7 per cent moisture in the fuel. His figures for labor should be doubled. For average fuels the moisture percentage should be doubled, and for the real field as mentioned by the author at least quadrupled for coal with 30 to 35 per cent moisture.

Referring now to (*a*) under Pulverized Coal vs. Stokers, the writer would inquire if a furnace suitable for lignite will handle anthracite. High overloads are spoken of freely and he would also inquire just what ratings have been sustained or even reached to confirm this.

Stokers are criticised in (*c*) as requiring more area for high overloads than pulverized-fuel burners. Has this been proved to be commercially true? With chain grates and coals such as mentioned in the average pulverized-fuel test, ratings of over 250 per cent are sustained for long periods, and peaks swung for short periods beyond this rating. Have any pulverized-fuel installations so far equaled this?

Referring to (*e*), the writer would state that not only is ash more easy to handle, but there is only about one-fourth of the usual amount, the remainder going out the chimney. This is one item of decreased cost that pulverized-fuel exponents seem loath to claim. We certainly must overcome this difficulty if we are to make pulverized-coal plants commercially successful, as our city and health ordinances will soon put the ban on this wide distribution of fine ash.

The writer would correct item (*f*) to say that coal burned on stokers may contain from 1 to 35 per cent of free moisture as fired. As a point of interest, he would inquire as to how readily pulverized coal picks up moisture when stored.

Under (*d*) in the following paragraph certain changes in the furnace are mentioned to suit various coals, also rather extensive changes in drying equipment. This is contrasted with stoker practice. The author presents as a favorable argument for pulverized-fuel burners that, with only a slight change in the furnace and some increased drying capacity, the equipment may be changed from one suitable for anthracite to one suitable for lignite. The writer would inquire in what commercial fuel market or location is this a valid benefit. What market receives both anthracite and lignite as steam coals?

Referring to the comparison of costs given under the heading Pulverized Fuel vs. Mechanical Stokers, the writer would question the estimated figure of 32 cents and would state that since the installation had its acceptance test ten months ago, the costs should not be concealed, but should be made part of the paper.

Reference to Table 1 in the complete paper would indicate that pulverizing cost would be

(*a*) For pulverizing and drying 12 per cent moisture coal	$0.516
(*b*) Labor (use 2 times tabulated cost)	0.08
	$0.596
Maintenance (use author's estimate)	0.03
	$0.626

As a matter of fact, in existing installations of from 500 to 600 tons daily capacity, the cost of drying and pulverizing fuel is over $1 per ton. This makes pulverized fuel prohibitive for steam-making purposes.

From all the figures presented, some good efficiencies are indicated when high-grade coals are burned (no tests are presented on low-grade coals). The advantage in efficiency, however, is insufficient to offset the increased cost of preparing the fuel, even on a basis of $5 fuel. This causes the pulverized-fuel burner to operate at a loss, regardless of the efficiency obtained. Fuel costs will have to be from 50 to 100 per cent higher before the increased cost of pulverizing will be justified, unless pulverizing and drying costs decrease materially.

Further, no modern ratings are recorded in the paper; furnace and slag troubles are minimized; quick pickups of boiler load over a wide range of rating are not proved and seem very problematic; ash from chimneys is at present a prohibitive feature in cities.

FRED'K A. SCHEFFLER (written). I cannot agree with Mr. Harrison in his statement that when a boiler is being run with pulverized coal it is not necessary to have more than 0.10 to 0.15 in. draft at the damper of the boiler, and consequently the boiler could be operated with stacks about 30 to 35 ft. in height. It is a well-known fact that it is necessary to have at least 0.10 in. in the furnace, and that the average water-tube boilers have a frictional or draft loss through the boiler of about 0.30 in. when run at rating, and when run at 200 per cent of rating this draft loss is almost double, or 0.60 in. Consequently, the stack would have to be at least 125 ft. in height in order to be sure that there is sufficient draft to overcome the frictional resistance through the boiler and allow a suction of at least 0.10 in. in the furnace.

W. N. BEST[1] (written). I should like to inquire how many open-hearth furnaces there are in the U. S. that are successfully burning pulverized coal, and for how long a period they have been operated.

The Boiler Test Code Committee of the A.S.M.E. would like to know of large power plants that are and have been successfully burning pulverized coal for a period of, say, 4 years. We have endeavored to locate such plants for some time in order to examine same and secure some data for the Society. I am aware that many plants have experimented with pulverized coal in the generating of steam, but results were very disappointing.

[1] Pres., W. N. Best, Inc., New York City.

At the beginning of Mr. Harrison's paper, he states: " . . . and the shortage in the supply of crude oils which have become of too great value for ordinary fuel purposes." This, I think, is misleading, for statistics prove that the production of oil has never before been so great, and the demands for it never so great, as today. In Mexico alone there are many reservoirs as large as lakes filled with crude oil awaiting transportation, and hundreds of wells are capped awaiting to be turned on to meet the demand.

The increased price of coal and the liability of further increases in its price have compelled many boiler plants along the Eastern Coast to change to oil as fuel, and many more contemplate changing soon. The cost of oil is now very attractive in boiler plants owing to the fact that it only requires 147 gal. of oil to represent a long ton (2240 lb.) of bituminous coal, the coal having a calorific value of 14,000 B.t.u. per lb. One man can fire and water-tend twelve 300-hp. boilers. Oil is so attractive at the present time as a fuel along the Atlantic Coast that I believe it will only be a matter of a year or a year and a half until all the larger power plants will use Mexican oil as a fuel in their boilers.

It is my opinion from close observation and study that the two distinct fields for pulverized coal are the furnaces of rotary kilns and copper matting furnaces. Both of these are constructed so that the building is quite open, and there is practically no liability of explosions being caused by spontaneous combustion. I believe the large quantities of poor coal and lignite that we have in our country can be successfully burned in combination with oil, the coal and lignite referred to being, of course, in the pulverized state. By this combination practically perfect combustion can be attained and maintained at all times, and this combination could be of value owing to the low calorific value of the coal and lignite, and the high calorific value of the oil. The process of burning this combination of fuels would not be by mixing them together, but each fuel should be delivered separately to the furnace.

W. G. DIMAN[1] (written). So far as the better grades of bituminous coals are concerned, I think that the cost of drying, pulverizing, conveying, feeding and the first cost of the apparatus, together with the fact that all grades of fuel can be burned with a tolerable degree of smokelessness and efficiency in the regular stoker apparatus, will restrict the use of pulverized coal for boiler purposes to special cases. If low-grade waste coal can be utilized for pulverized fuel there is a great field for its use. There must be some limit, however, in the use of low-grade fuel, for the cost of grinding would eat up any advantage in the economy. Where low-grade fuels are high in ash and slate there should be a limit to the proportion that one can afford to grind. The use of high-ash coal will be bad, as it will accumulate rapidly and be difficult to remove, especially if it slags to any extent. This would occur more where the ash deposits are within the limit of the flame. With anthracite, especially culm and of that nature, it might be difficult to pulverize and must be finely pulverized; it needs a higher temperature for combustion, burns more slowly, and in certain boilers like a H. R. T. it would require plenty of brickwork and a large combustion chamber to avoid the chilling effect and to maintain combustion. The best coal to use is one high in volatile and low in ash. Such a coal would not be a very satisfactory one for outside storage in large quantities due to the likelihood of spontaneous combustion. In order to successfully use the pulverized fuel, I am of the opinion that the best results can be obtained by designing the furnace and equipment to meet a specific grade of fuel. I do not think that the average cost per ton for getting the coal from the car into the boiler is as low as stated, and if the overhead is also taken into consideration it will run still higher.

E. H. PEABODY[2] (written). In Mr. Harrison's paper I note that among other important matters he mentions three points which occur to me as particularly significant in the use of pulverized coal for boiler purposes:

[1] Supt. of Power, Amoskeag Mfg. Co., Manchester, N. H. Mem.Am.Soc.M.E.
[2] Marine Dept., The Babcock & Wilson Co., New York City.

1 Very large furnace volume required, or, in other words, the fuel must be burned under conditions which imply a very low rate of combustion per cubic foot of furnace volume;
2 The continual effort necessary to keep the boiler tubes, and, to a less degree, the furnace itself, free from slag and clinker caused by the refuse in the coal; and
3 The very high, and apparently inaccurate, boiler efficiency reported in the tests of August 12-13, 1918, which appears to be due to crediting the boiler with work done by the coal driers.

If, as seems to me proper, the boiler efficiency is figured on the basis of the heat value of the dry fuel, the result should be 76.3 instead of 85.2. The degree of efficiency obtained in the drier itself would in no way affect the results obtained in the boiler in actually transferring the heat in the fuel to the steam.

Oil fuel is undoubtedly superior to all others for boiler purposes. The furnace volume required for this fuel to give satisfactory results is about one-quarter the furnace volume specified in the paper for pulverized coal.

The similarity of action in many features between oil fuel and pulverized coal appears to me to constitute one of the principal attractions of the latter. It would seem, however, that the large furnace, with its extra first cost and extra radiation loss, together with the difficulties due to slag and their effect on operation, would offset the desirability of pulverized coal to a very large extent.

ALBERT A. CARY[1] (written). To many who have not had occasion to keep informed concerning the previous use and past applications of powdered coal as a fuel, the idea seems to be prevalent that such fuel is a recent development, holding almost unlimited possibilities for all kinds of furnace applications and capable of easily and cheaply accomplishing phenomenal results.

As a matter of fact, inventors have been struggling for almost a century to make powdered coal a practical and successful fuel.

In 1831 an English patent was issued to J. S. Daws for a process for burning powdered coal, and this was rapidly followed by a large number of patents relating to this subject in England, the United States, Germany and elsewhere.

In 1881 a United States patent was issued to C. H. Palmer describing the means for feeding fine coal to a locomotive boiler with an air blast, while in 1870 Whelpley & Storer began to take out a series of patents for using pulverized coal in reverberatory metallurgical furnaces. In 1876 an elaborate series of tests was conducted by the Bureau of Steam Engineering of the Navy Department under the direction of B. W. Isherwood—using the Whelpley & Storer pulverized-coal system applied to a steam boiler.

Thus we are able to understand that the preparation and use of pulverized coal fuel is by no means a recent development, and notwithstanding the considerable expenditure of money, effort and ingenuity by many inventors, including men whose past experiences qualified them to carry on such work; most of these older productions have been scrapped so that today we have left merely the benefit of their varied experiences, which has, nevertheless, proved a valuable source of information for the more recent developments in the preparation and use of pulverized coal.

Turning now from this record to the more recent developments, it will require but little investigation to find that during the last decade (or even for a much shorter period) there have been many powdered-coal installations which have either been rejected or found to give poor satisfaction.

After the presentation of such facts, I may be accused of condemning the use of pulverized fuel as a practical and efficient fuel.

On the contrary, in the light of my experience and with the evidence presented by many satisfactory equipments now in operation, I am an unqualified advocate of the use of such fuel, but I must limit my endorsement to applications where a desirable grade of fuel is available—where proper preparation of the fuel and proper furnace conditions can be obtained and where other methods for burning the available fuel are inferior—to accomplish the desired heating.

About 24 years ago I was called upon to assist in the development of a pulverized coal equipment for a cement plant, and since that time I have been called upon to test, investigate and design a number of pulverized coal equipments for cement kilns, boilers, metallurgical and other industrial furnaces and thus have had an opportunity to follow the development of this art since the early days of its practical commercial adoption in this country.

PULVERIZED COAL IN CEMENT PLANTS

Mr. Harrison has very properly given first place in his paper to the use of pulverized-coal fuel in the rotary kilns of our cement plants, as not only do we owe the present development of our pulverized-coal equipments to the pioneer work done in their development at such plants, but the very form of these long, cylindrical, refractory-lined furnaces furnishes us with the ideal construction for the use of this form and kind of fuel.

They permit the use of the long, air-projected current of finely powdered fuel, giving it ample time to complete its combustion while being held in suspension and without direct flame and ash impingement upon any impeding furnace wall.

The simplest form of burner and fuel-feeding device can be used with such furnaces, and the ash resulting from the combustion of this finely ground coal causes little or no trouble, providing the ash content and its quality remains nearly constant, as this ash drops down and mingles with the burned clinker without materially affecting the quality of the final product.

PULVERIZED COAL IN METALLURGICAL FURNACES

Next in order of desirability in the way of furnace design for the use of pulverized coal, we have our reverberatory metallurgical furnaces of great length (100 to 150 ft.), such as are used for copper smelting, where the flame is projected from the front toward the rear of these furnaces over the charge of ore on the hearth.

Without the exceptional facilities for taking care of the ash resulting from the combustion of the pulverized coal as found in the rotary cement kilns, ash troubles proved to be a pretty serious matter with the early pulverized-coal installations applied to these furnaces about a dozen years ago.

The ash fused and formed a slag blanket over the top of the ore charge and stuck to the interior of the flue outlets in a way to block these passages; but these and other associated troubles were finally overcome by stopping the infiltration of large amounts of cold air, by stopping the practice of charging large quantities of cold ore into the furnace, by using a better design of burner and coal-feeding device, and by a more careful preparation of the pulverized coal.

By these means a much higher temperature was maintained in the furnace, a very much higher ratio of charge to fuel used was obtained, and a better and more constant regulation was secured at the burner. Then pulverized coal began to be recognized as a most excellent reverberatory fuel.

When pulverized coal was used as a fuel for shorter and smaller reverberatory furnaces and directly fired into their interiors, the above-named troubles were accentuated and due to the imperfect absorption of the heat in these furnaces, the use of waste-heat boilers generally became a necessity in order to obtain efficient results. Accumulations of more or less fused ash piled up rapidly on the heating surface of these boilers necessitating frequent cleanings. Experience has shown that the reversing type of furnace for the production of open-hearth steel, such as described in Mr. Harrison's paper, is the best design of pulverized-coal furnace for that purpose. Checkerwork and baffle walls must be specially designed for use of this fuel.

A modification of the above-described reverberatory furnace, consisting of an extension furnace in front of the main furnace chamber, so proportioned as to retain a large percentage of the ash within this chamber, makes a highly efficient equipment. It requires a burner equipment permitting a close regulation of its

[1] Consulting M. E., New York City.

coal and air supply, and one which will produce a short, brush-like flame close up to the burner, which means a very rapid combustion and a high temperature in the combustion chamber.

In some recently-built extension furnaces a large percentage of the ash is separated from the body of the flame and drops into a comparatively cool part of the chamber as a fine, dry ash mingled with but a small percentage of fused ash nodules, which do not interfere with the easy removal of the refuse from the furnace bottom.

With other recent designs of extension furnaces, where very high temperatures are maintained at the burner outlet, the rapid fusing of the ash is expedited, which refuse drops to the slag pit below in a molten mass and under proper conditions may be drawn off through tap holes from the bottom of the extension furnace.

Such a design of extension furnace has been installed by the Lopulco Company in a steel plant near Pittsburgh, in connection with their heating furnaces, where it has given excellent satisfaction.

Application to Stationary Boiler Plants

The application of pulverized-coal fuel to steam boiler furnaces meets with many challenging difficulties, which, however, recent developments have done much to overcome. A number of such installations are in use, some of which are showing very desirable economy and producing a material increase in the steaming capacity of the boilers.

Great care must be taken to prevent any of the unconsumed coal from coming in contact with the chilling water-containing surfaces of the boiler, which, therefore, demands the use of an extension furnace in which the complete combustion of the coal is accomplished, and in which the proper handling of the fine ash (and its resulting slag) is provided for.

All that has previously been said concerning the requirements needed for extension furnaces applied to short reverberatory furnaces apply with equal force here.

With the intense heat generated in burning pulverized coal, much trouble has been experienced in improperly designed boiler furnaces due to the rapid melting down of the refractory linings, which may also be subjected to the scouring or cutting action of impinging ash, thus requiring frequent and expensive relining.

Process of Combustion of Pulverized Coal

Pulverized coal *must* be burned while suspended in the current of air which accompanies it into the furnace.

As the finely divided coal enters the highly-heated furnace, any moisture contained by each minute particle is first driven out, and if this is excessive, it will form a steam cloud around the particle and suppress its further rapid combustion, thus defeating to a greater or less extent the purpose for which the coal was prepared.

One of the necessities for supplying the furnace with very dry pulverized coal is thus appreciated.

With little or no moisture present, the next effect of the very high surrounding temperature in the furnace is to almost instantly distill off the volatile matter occluded in the coal as this gas is liberated at a comparatively low temperature and thus, with properly designed furnace and burner, the dust cloud entering the combustion chamber suddenly becomes thoroughly saturated with a highly inflammable gas, mixed with an ample supply of air.

Under these conditions the gas is raised to its ignition temperature with great rapidity, and the flame produced is propagated with intense speed throughout the atmosphere of fuel and air entering the furnace; all of which is simultaneously subjected to the same action.

With the intense degree of heat thus generated, not only is the temperature of the furnace maintained to stimulate further combustion, but the particles of fixed carbon (or flecks of coke) left behind, after the volatile gases have been driven out of the coal, have their temperature raised with great rapidity to their temperature of ignition and so are most speedily burned leaving behind the non-combustible matter (which we have called ash) to be more or less effectively taken care of in a properly designed furnace, or to give great trouble in furnaces where its importance has been ignored.

Mr. Harrison very tritely states that "The *finer* the coal is pulverized, the more efficiently it can be burned."

With the above analysis of the process of combustion before us, we can more readily understand the reason for this statement. Not only does the greatly increased fuel surface (presented to the highly heated interior of the furnace) facilitate the more rapid distilling off of the volatile gases, but with the volume of the particle itself greatly reduced, the penetration of the heat to its interior takes place in a very much shorter period of time. Aside from these advantages the important fact stands out that the Law of Mass Action applies to such combustion (which is akin to the action of explosives) by which we find that the amount of the reaction in a unit of time is proportional to the active mass, or, in other words, the smaller the particle of coal, the smaller the number of gram molecules of combustible matter found in the unit mass.

Under these most favorable conditions, the velocity of combustion is greatly accelerated, which is the principal object striven for when pulverized coal is chosen for a fuel.

A moment's thought will recall the fact that the volume of a mass varies as the cube of its diameter and thus a particle of coal 1/100 in. in diameter has eight times the volume that is found in another particle that is 1/200 in. in diameter.

The effect of the decreased surface in proportion to the mass results in a very great retardation of the combustion of the larger particles as is very plainly shown in the photographic study of the combustion of coal dust in Bulletin No. 102 of the Bureau of Mines, entitled The Inflammability of Illinois Coal Dusts on Plate IV. B and Plate V. B.

Uniformity in the size of pulverized particles is also very desirable, as we can readily understand that if we have mixed a considerable percentage of each of the above named sizes of coal fed to our furnace, the combustion of the larger size will proceed much slower than the burning of the smaller size, which condition not only reduces the velocity of combustion of the total mass, but it prevents the production of that "gas-like flame," which Mr. Harrison refers to.

When such grades of coal, averaging from 30 to 40 per cent of volatile matter, as described above, are pulverized so that over 90 per cent will pass through a 200 mesh screen, the finer coal accompanying it does not seem to materially affect its even rapid burning effect in general furnace practice; and further, as Mr. Harrison has stated, with this very fine pulverization, which insures rapid and high temperature combustion, the sulphur in the coal burns rapidly to SO_2 gas, which passes to the stack without affecting the product of the reverberatory furnace.

When a coal, running high in fixed carbon, is used as pulverized fuel, we have a different and less desirable set of furnace conditions.

Lacking the production of an ample supply of volatile combustible gases given off by the coal at a comparatively low temperature, and also lacking the heating effect which the burning of these gases produces, to hasten the combustion of the associated fixed carbon, we must necessarily maintain a higher furnace temperature to ignite this fuel, and to obtain the best possible results, the coal should be ground finer, as it will be found that this fuel is slower to ignite. Much of such coal carries a higher ash content, which still further complicates matters and lowers the heat value of the coal.

Mr. Harrison gives a table purporting to give the cost of coal pulverized-coal system upon which these figures are based nor question the reliability of these figures. Nothing is said of the pulverized-coal system upon which these figures are based nor the class of machinery or equipment included.

There is a considerable range in cost of equipments as furnished by different concerns and the figures presented in this table appear low for the better class of equipment.

Much depends upon the class of equipment one is willing to in-

stall, which has much to do with results obtained including cost of future upkeep.

There are many elements entering into the cost of such equipments. For example: should one be obliged to handle very wet coal in the coal dryers, the normal capacity of the drier would be reduced and either larger driers or more driers would be required to obtain a fixed amount of dried coal, which would also require a greater building space.

Again, should one decide to grind the coal very fine to obtain maximum furnace results, the output capacity of the pulverizer would be materially reduced below that needed for coarser pulverization and more or larger mills would be needed, and thus I might continue this list.

Whereas, Mr. Harrison's total cost for pulverizing 80 and 90 tons of coal per day agrees pretty well with the cost estimate given in this table, his cost for producing 100 tons per day runs 21 per cent higher than the figure shown in the table.

In looking over the log of the boiler test quoted by Mr. Harrison I note what appear to be a few discrepancies, but lacking full and complete data, I have been unable to check them up as carefully as I would otherwise do.

Taking his analysis of furnace gases, he gives the maximum result obtained as 15.4 per cent of CO_2 and 5.6 per cent of C with no CO.

This is consistent and possible.

He then gives his minimum result obtained as 12.2 per cent of CO_2 and 3.2 per cent of O with no CO; the sum of these gases giving 15.4 per cent with 84.6 per cent of N by difference.

There is evidently some discrepancy here, as I do not see how it is possible to burn such a coal as he indicates so as to obtain such an analysis.

The percentage of boiler efficiency given in this table as 85.22 per cent seems entirely inconsistent and I cannot find sufficient indication contained in the other data submitted to assure me that the total losses in the performance of this test amounted to only 14.78 per cent.

One very interesting question in connection with this test is, What means were used for accurately weighing the pulverized coal used? As a matter of secondary importance I might also ask, What means were used for ascertaining the weight of water fed to the boiler?

J. E. MUHLFELD[1] (written). Mr. Harrison's excellent paper reviews data that conform in general to my experience during the past few years in the development of systems for the more effective and economical utilization of coals and lignites in pulverized form, for stationary, locomotive and marine boilers, and for metallurgical and chemical heating furnaces, and the information that he has given will be of great assistance to existing and prospective users of this method of firing and burning solid fuels.

Until recently power-plant capacity and efficiency have been dependent upon combustion possibilities. Fortunately, this has now changed and the problem is in boiler design and construction.

In the log of test on a pulverized-fuel-burning stationary boiler given by Mr. Harrison, the operating capacity deductions on account of the power and other items necessary for the preparation of the coal in pulverized form should be 3.17 per cent, in place of 4.22 per cent, as used in arriving at the net efficiency. This figure of 3.17 per cent compares with the power necessary to operate mechanical stokers, and which, in an installation of this kind, would amount to from 2½ to 5 per cent, varying with the boiler load carried.

In connection with this log of test data it may be of interest to give the heat balance for the same 24-hour run, which is as given in Table 2.

Furthermore, to show the definite control over stand-by losses by the use of the same pulverized-fuel system, at the same plant, the data in Table 3 are of interest.

To further show the positive control over the combustion, the performance of one of these boilers in Table 4 is of interest. During the 14-hour run, from 6 p. m., February 1, to 10 a. m., February 2, for which period the boiler was sealed and operated at about 150 per cent rating, it will be noted that there was a change of only 0.2 per cent in CO_2 and 0.4 per cent in O_2, and no slag was produced.

Observations made of the stack from the outside of the power-plant building, when operating the pulverized-fuel and the stoker-equipped boilers in combination and independently have also demonstrated that no smoke was produced from the pulverized-fuel-fired boilers.

The four pulverized-fuel-equipped boilers at this plant were cut in on the main line over 90 per cent of the time during the months of February and March, 1919, and when line banked no fuel was required.

Referring to various information as set forth in Mr. Harrison's paper, I would like to point out the following:

I can hardly agree with Mr. Harrison that the equipment for

[1] V. P., Ry. and Industrial Engrs., Inc., New York; Mem. Am. Soc. M. E.

TABLE 2 HEAT BALANCE FOR BOILER TEST IN TABLE 3 OF MR. HARRISON'S PAPER

Ultimate analysis of pulverized Indiana and Illinois screenings as fired, given in percentages;

1	Moisture	3.20
2	Carbon	55.66
3	Hydrogen	4.47
4	Oxygen	19.77
5	Sulphur	1.97
6	Nitrogen	1.45
7	Ash	13.48
		100.00

The distribution of the calorific value of one pound of coal as fired among the several items of heat utilized and lost is as follows;

	B.t.u.	Per cent.
Heat absorbed by boiler	9,934	85.22
Loss due to evaporation by moisture in coal	41	0.35
Loss due to heat carried away by steam formed by burning of hydrogen	493	4.22
Loss due to heat carried away in dry flue gases	975	8.37
Loss due to carbon monoxide	0	0.00
Loss due to combustible in ash and refuse	51	0.44
Losses due to heating moisture, in consumed hydrogen, hydrocarbon, radiation and unaccounted for	163	1.40
Calorific value of fuel as fired	11,657	100.00

TABLE 3 SHOWING CONTROL OVER STAND-BY LOSS

Date	August 18-19, 1918
Boiler No. 5	Edge Moor, Rated 468 nominal hp.
Fuel feed shut off, uptake damper closed and auxiliary air inlets closed	9.00 p.m.
Boiler steam outlet to header closed and 175 lb. steam on boiler	9.20 p.m.
Safety valves released about one minute at the following times (p.m.) 10.08, 10.15, 10.25, 10.38, 10.43, 10.52, 11.02, 11.09, 11.18, 11.28, 11.38, 11.48, 11.52.	9.40, 9.55,
Steam on boiler 155 lb. when fuel feed started and boiler steam outlet to header opened	7.00 a.m.
Drop of steam pressure in boiler, from 9 p.m. until 7 a.m., or during 10 hours while fuel feed was off and during which time safety valves popped 15 times, for one minute each, or a total of about 15 minutes	20 lb.
Time required to bring boiler from 155 to 175 lb.	4 minutes

TABLE 4 SHOWING POSITIVE CONTROL OVER COMBUSTION

Date	Time	CO_2	O_2	CO
February 1, 1919	5.00 p.m.	13.00	6.00	0
	.....	13.6	4.2	0
	.....	13.2	5.2	0
	6.30 p.m.	13.0	6.0	....
	.....	13.8	....	....
	.....	14.2	3.2	0.2
	.....	14.4	....	0
	.....	14.6	3.4	1
	8.00 p.m.	14.8	4.6	0
February 2, 1919	10.00 a.m.	13.0	5.0	0

preparing pulverized coal has been developed past the experimental stage. There is still considerable to be done in this direction, particularly with respect to the elimination of the reabsorption of moisture and of entrained moisture, which results in condensation in the dry- or pulverized-fuel bins and the consequential trouble that it causes. The type and operation of drier and pulverizer has a great deal to do with these factors, and experience has demonstrated that certain fuels require special treatment in that regard or trouble is bound to occur.

From my experience, when pulverized fuel is used for steam generation the detrimental effect from the ash and sulphur content is nil, regardless as to the melting point of the former.

The economic use of coke breeze is at this time problematical, as the expense of preparing the fuel will, in a large number of cases, offset the fuel value of this by-product. A study should be made of each specific application before the use of coke breeze is gone into.

The utilization of the full thermal value of anthracite silt has been developed to a point where there are no commercial obstacles in its way, and this in itself will release an equivalent amount of commercial size of coal. The shipment of silt to a considerable distance from the mines, however, may not be economical, but the power consumption by the mining and nearby industries is sufficient for the full utilization of this by-product, which should make it unnecessary to ship the silt to other points.

The author's specific statement as to how the coal should be pulverized is not in conformity with my experience on this subject, as the degree of fineness should vary with the character of the fuel. The results of careful analyses and tests have demonstrated that this degree of fineness for effective and economical use cannot be arbitrarily set down, as it varies with the volatile content and the combustion characteristics of the fuel handled.

Commercially the expense of pulverizing increases with the degree of fineness, and consequently the coarser the particles of the fuel the less the cost chargeable against the pulverizing process, for which reason it is advantageous to use coarse pulverization whenever the character of the fuel is such that this is feasible.

From my experience the author's tabulated costs for pulverizing are somewhat misleading, as the cost for preparation will vary over wide ranges. While the information as set forth is valuable from a general standpoint, it must be used with care for the reason that it is not susceptible to specific adaptations.

In the case of open-hearth practice the system to be used for burning the pulverized fuel determines the degree of fineness. The high-velocity method of burning, such as described, will, of course, require much finer grinding than a low-velocity method such as obtains with other systems in which the time limit is increased, thereby permitting combustion to take place more slowly with the same thermal results.

By using a low-velocity flame the length of from 6 to 8 ft. mentioned by the author can be decreased.

Some of the steel companies have reduced their pulverized-coal consumption per ton of output to a little less than 450 lb. instead of 500 lb. as given in the paper.

It has been found in operating practice that pulverized-fuel-burning furnaces, under the best system of combustion, can be reduced to a little less than 1 cu. ft. of volume per b.hp. developed, and that the rating can be increased up to the capacity of the furnace to keep the lower tubes of the boiler free from honeycomb and still maintain effective combustion below the boiler-tube line.

The best system of combustion necessitates—

1 Proper preparation of the fuel
2 Effective means for feeding
3 Furnace properly designed and equipped with auxiliary air supply to insure a distinct hot zone and a distinct cold zone, and gas areas and baffles and draft coördinating with the foregoing.

The pressure at which pulverized fuel can be admitted to the furnace has been found, in service practice, to be not more than plus 0.05 in. of water at the burner nozzle.

In my opinion a boiler cannot be successfully operated at any capacity with the natural draft obtained with a 30- to 35-ft. stack, the reason being that the friction losses of the gases passing through the boiler tubes, and the gas areas produced by the baffles, will reduce the draft, due to this low height. When operating at full capacity about 0.10 in. of water draft in the furnace, plus the friction losses through the boiler setting, is the minimum under which any pulverized-fuel boiler installation should be operated. Anything less than this will limit the factor of regulation and will tend to cause constriction of heat to the furnace chamber and result in slag, which latter, in all cases, is to be avoided. Any pulverized-fuel-burning installation, in combination with a steam generator, in which the formation of slag is of any considerable consequence, can be taken as a failure from the standpoint of effective and economical results.

Under proper combustion conditions the use of a hand-lance steam jet to clean the bottom tubes as recommended by the author is unnecessary. The top of the tubes should, of course, be kept free from the accumulation of ash, which acts as an insulator and which tends to carry the heat in the ash and gases through the boiler to the stack.

While any ash accumulation in the bottom of the furnace should be periodically removed, at the same time with a proper design of hot-zone and cold-zone furnace any ordinary accumulation should not convert into slag.

In comparing pulverized equipment with stoker equipment, the author states that considerably less excess air is required with the former. The amount of air injected with the fuel into the furnace, however, should be a negligible percentage of that required for combustion, the only function of that air being a conveying and commingling medium. In the Edge Moor installation to which the author refers, the percentage of air entering with the fuel is about 1½ per cent of that necessary for combustion, the remaining 98½ per cent being induced by the stack.

[Mr. Muhlfeld supplemented the foregoing discussion and comment upon Mr. Harrison's paper with data upon performance of pulverized-fuel equipment in locomotive and marine practice, which constitute a most acceptable addition to his paper on Pulverized Fuel for Locomotives, given at the annual meeting, December 1916, and published in Vol. 38 of TRANSACTIONS. Space does not permit the publication of these in this issue, but it is hoped to present them later.—EDITOR.]

EDWIN LUNDGREN,[1] who opened the oral discussion, called attention to the large combustion space specified in Mr. Harrison's paper for a boiler burning pulverized fuel as compared to a stoker-fired boiler, especially when the boiler was to be operated at, say, 300 per cent of rating. In the matter of draft, he thought Mr. Harrison had not taken the resistance of the boiler into consideration in specifying but 0.10 to 0.15 in. For the ordinary type of boiler a draft of about 0.15 in. was required at 100 per cent rating, which increased to about 0.7 in. for 300 per cent. rating. A stack 100 ft. high would give about 0.6 in. draft, so that a height of 35 ft. was out of the question.

As to the low efficiency (63 to 65 per cent) of stoker-fired plants mentioned in the paper by Messrs. Scheffler and Barnhurst, he would cite the Detroit Edison plant where an average efficiency of 76 per cent was maintained throughout the year, and where Dr. Jacobus' series of 24-hour tests showed efficiencies of 80 per cent or better. Also, the Cincinnati Gas & Electric Co. maintained a combined boiler and furnace efficiency of about 80 per cent in their plant constructed to maintain 365 per cent maximum capacity and 300 per cent continuous capacity.

There was no question but what pulverized-fuel equipment would be useful in burning some of the cheaper grades of fuel, like some of the western fuels, for which it seemed no real type of stoker had been designed. He did not believe, however, that it would be generally applied to modern central stations, for one reason because the pulverized-fuel-equipment buildings, to judge from the slides shown, appeared to be about as large as power stations.

[1] Chief Engineer, Stoker Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

C. F. HIRSHFELD[1] said that in modern boiler plants the chief losses were due to carbon in the ash and to heat escaping up the stack. The Detroit Edison Co. operated under good conditions with 10 per cent of carbon in the ash, or a very small per cent of the fuel originally fired, and with but 10 to 12 per cent of excess air. If use of powdered fuel would make it possible to burn all the carbon in the coal—which was contrary to his experience—and with no greater amount of excess air, the saving effected would still be of little consequence. He believed in using powdered coal where conditions were such that it was distinctly economical to do so, but these did not obtain at the Detroit plant. In his opinion there was a greater chance for improvement in the turbine end of the plant than in the boiler room.

As to greater uniformity of flame and temperature, which conduced to larger life of the furnace lining, he believed that the advantage was with the stoker with its smooth bed of incandescent fuel. While powdered fuel might be more adaptable when a wider range of fuels was available, the stoker was just as adaptable so far as the art had developed.

In the paper by Messrs. Scheffler and Barnhurst, the power for operating a stoker was stated to be 2 per cent of the total boiler hp. In the Detroit Edison Co.'s plant, however, it was much less than 1 per cent with the boilers operated at 200 per cent of rating.

H. WADE HIBBARD[2] said that in a larger plant he had in mind an increased efficiency resulted from adding moisture to coal that had dried out too much before it reached the stokers. He therefore asked whether drying was necessary in order that the coal might be thoroughly pulverized, and also whether there had been any experiments performed in introducing steam along with the powdered coal. Affirmative replies were respectively made to these queries by Messrs. Scheffler and Barnhurst, the latter adding that he did not know whether the introduction of moisture had increased the efficiency.

P. A. POPPENHAUSEN,[3] referring to a statement made by Mr. Lundgren, said that his company had successfully adapted the chain-grate stoker to the burning of lignites of all grades and containing as high as 30 per cent of moisture, and that 24-hour tests had shown efficiencies of from 76 to 78 per cent. The power to operate a stoker was insignificant—less than 0.5 hp. per unit, whether a 200-hp. or a 600-hp. unit. He thought Mr. Scheffler's figure of $64,000 low for the cost of a pulverizing plant of 100 tons daily capacity, and asked how large a plant should be in order that this cost would not be prohibitive.

JOHN VAN BRUNT,[4] calling attention to Mr. Harrison's reference to coke breeze, said he could state that over 75,000 hp. of boilers equipped with traveling-grate stokers were now satisfactorily operating on this waste fuel in the large steel plants and gas works of the country.

GILBERT A. YOUNG[5] spoke of successful experimental work carried on for the past two years at Purdue University on a furnace for burning crushed, undried coal containing as high as 20 per cent moisture. The particles after crushing ranged from the size of a match head down to powder passing a 200-mesh screen. He hoped to submit a paper later giving comparative tests of the crushed-coal furnace and several types of stokers, all operating under the same conditions.

W. P. FREY[6] said that his company burned 1,000,000 tons of coal a year for steam and electric power, and that he was interested in pulverized fuel as a possible means of utilizing the twenty-odd million tons of small coal lying on the ground in the anthracite regions. But as it was said to take twice as much power to pulverize anthracite as bituminous coal, and as the minimum wage for the anthracite union laborer was 43 cents per hour, this would make the cost of pulverizing the $1 coal in question about 75 cents, and he did not see how pulverizing would make up for this enormous difference. Firing a boiler at a high rating with anthracite required far more draft at the damper than the 0.10 to 0.15 in. mentioned in Mr. Harrison's paper, and in consequence stacks much higher than 40 ft. The fire-brick problem was a very important one, and he would be obliged if Mr. Scheffler or Mr. Barnhurst would give specifications for bricks that in the long run would stand the steady temperature of over 3000 deg. that they would have with their low supply of air, unless they reduced the temperature in the combustion chamber.

C. W. LOTZ,[1] in reply to Mr. Frey, said that in his experimental plant the cost of pulverizing anthracite was but 33 instead of 70 cents a ton. They were also burning coke breeze efficiently. As to stack heights, it was to be remembered that the furnace itself acts as a big stack and drives the gases up through the first pass of the boiler.

W. L. WOTHERSPOON[2] told of tests he had made some ten years ago in South Africa on a Bettington boiler fired with pulverized fuel and a B. & W. boiler with a chain-grate stoker. Both boilers were 1000-hp. units and the efficiencies obtained were practically equal. There were low-grade fuels (9500 B.t.u. and less) available in the Transvaal, and the results obtained with pulverized fuel were such that the plant was still in operation.

Lately he had been paying attention to the use of powdered coal where the combustion took place under pressure—for the generation of heat in a blast furnace smelting nickel ores. On a continuous 18-day run it had been found possible to replace 50 per cent of the coke used, which cost twice as much as bituminous coal. At the Tennessee Copper Co.'s smelter he had not only been able to replace all the coke with powdered coal, but to actually do the smelting with 25 per cent less fuel. Even better results were shortly to be expected. Their pre-war cost for drying and pulverizing was 40 cents per ton. Now it was practically double that figure.

The impression prevailed in the United States that the screw feed was necessary, but in Canada he had experimented and found that by using compressed air at 70 lb. pressure, 2½ tons could be transmitted in 5 min. through a 3-in. pipe over a horizontal distance of 1200 ft. and then elevated 60 ft. This method might prove available for the use of a central pulverizing plant supplying small, isolated power plants through an underground pipe line.

W. E. SNYDER[3] felt that while pulverized coal was an ideal fuel in the cement plant, there were, nevertheless, many problems to be solved in regard to its use in steel furnaces and under boilers. The best modern stoker-fired plants showed very high efficiencies, and with the same expenditure of intelligence the pulverized-coal plant might be brought to equal them.

He had experienced difficulty in obtaining definite facts regarding performances of pulverized-fuel installations, and was skeptical as to the accuracy obtained in measuring the coal by observing the revolutions of the feed screw, for it did not always give the same quantity per revolution. Apropos of accurate measurements, Mr. Snyder caused considerable amusement by telling of the man in charge of a small power plant who had succeeded in overcoming troubles he had experienced with a venturi meter by merely boring out the narrow part!

Narrowing down the comparison of the two methods of getting coal into the boiler furnace, he said, it resolved itself into a very simple matter of reducing waste in the ashpit and up the stack.

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[1] Chief, Research Dept., The Detroit Edison Co., Detroit, Mich. Jun. Am.Soc.M.E.

[2] District Engineer, U. S. Fuel Administration, Columbia, Mo. Mem. Am.Soc.M.E.

[3] Pres., Green Engineering Co., Chicago, Ill. Mem. Am.Soc.M.E.

[4] Chief Engineer, Combustion Engineering Corpn., New York. Mem. Am.Soc.M.E.

[5] Head of Department of Mechanical Engineering, Purdue Univ., Lafayette, Ind.

[6] Fuel Engineer, Lehigh Coal & Navigation Co., Lansford, Pa.

[1] Pottsville, Pa.

[2] Consulting Metallurgist, International Nickel Co., New York.

[3] Mechanical Engineer, American Steel & Wire Co., Pittsburgh, Pa. Mem. Am.Soc.M.E.

and a possible saving in repairs and maintenance of the means employed to handle the fuel.

W. F. VERNER[1] gave estimates that had been prepared covering the comparative costs of operating six 2400-hp. boilers at the Ford Motor Company's blast-furnace plant with pulverized fuel and with stoker fuel. The estimated cost for the pulverizer equipment and buildings was $691,000 and for a corresponding stoker plant $475,000. The cost of pulverizing per ton, including fixed charges, power, maintenance, lubricants, etc., and labor (at $8 per day), was $0.76; for transmission from pulverizing building to boiler room, $0.25; and for boiler room, $1.13; or a total of $2.14. For a corresponding stoker plant the figures were: for transmission from breaker building, $0.24; boiler room, $1.66; total, $1.90. For a plant with twelve 2400-hp. boilers the total for the pulverized-coal installation was $1.63, and for the stoker equipment, $1.49. These figures, in connection with the higher estimated efficiency of the pulverized-fuel plant, indicated for it a saving of 4 per cent over the stoker plant.

One important point in favor of pulverized-fuel plants was that the stand-by losses were reduced to a minimum as compared with stoker installations, where the fires had to be banked over the shutdown periods. An additional reason for installing the former was that blast-furnace gas would be available for use under the boilers and in quantity sufficient to carry the light loads.

JOHN A. STEVENS thought that the matter of stand-by losses brought out by Mr. Verner a very important one. In New England factories running on one shift of 9 hours a day, the stand-by coal required in the best hand-fired plants ranged from 20 to 25 per cent of the daily consumption. This, of course, decreased with more shifts, or with continuous runs of, say, 72 hours, as in paper mills. With stoker-fired boilers there was a loss in running full load right up to washing-up time—usually 10 minutes before the quitting hour, and also when burning a bank of coal on the grates and then rejecting it. The elimination of non-productive fuel in shop power plants was also claimed as an advantage by the advocates of oil fuel or the purchase of power from central stations. A prominent engineer had told him that 2¼ per cent of unconsumed carbon passes out of the stacks of these large stations, and to obviate this he trusted that an effective silt separator would shortly be developed.

R. SANFORD RILEY[2] said that the papers and discussion were valuable in directing attention to the problem involved in all combustion—the carburization of air. The final question regarding the two systems of burning fuel under consideration was which was the better carburizer, and he felt that in the long run the simpler apparatus would win out.

EDWARD N. TRUMP[3] spoke of experiments he had made about 25 years ago in burning powdered fuel under a 300-hp. B. & W. boiler. The furnace used had too small a combustion chamber, and the ash accumulated and blocked the passages between the tubes in less than a week. This ash had taken up tar from the combustion products and clung to the tubes, and it proved very difficult to scrape off. It was important, therefore, to see that the combustion chamber was large enough, and, as noted in Mr. Harrison's paper, that the boiler tubes and surfaces were carefully and frequently blown.

H. G. BARNHURST, in closing the oral discussion, said that there were certain arguments in favor of pulverized coal for certain localities and for certain grades of fuel which could hardly be overcome by any other method of burning. One point which had not been brought out was the fact that by pulverizing coal and burning it in a furnace the boiler installation was made entirely independent of any particular quality of fuel. In the course of experimenting his company had burned coal with as low as 2 per cent of volatile matter and up to 40 per cent with an ash content running as high as 51 per cent, just to show that the percentage of ash did not affect or interfere with the combustion conditions. Mr. Trump's main troubles, he thought, were due not only to the small combustion chamber used, but also to the fact that his coal was not finely pulverized. He wished again to emphasize the fact that the coal must be pulverized to a very high degree of fineness in order to get good results—two or three hundred million particles to the cubic inch. This increased the surface exposed to the air about 700 times over that which it was in the form of lumps, and made it very much easier to effect combustion. Moreover, various grades of coal could be burned which could not be handled on stokers.

As to the volume of a furnace per pound of coal burned per minute, he would not care to assign any particular value, because all combustion chambers had different shapes. The essential feature was low velocity of the gases, for the brick became plastic at high temperatures, and if subjected to the action of gases at a high velocity, the under rows of lining would be destroyed.

The question of furnace firebrick was, of course, very important, and the higher the grade used the better would be the results. The ash accumulation in the bottom of the furnace by further refinements might be cared for by movable hearths so that it would not build up in the furnace and interfere with the operation. The ash going out of the stack, in some cases, was now being recovered to a certain extent, and there was certainly a field for recovering ash not only from pulverized-coal-fired furnaces, but also from stoker-fired furnaces, because the percentage of ash from many stoker installations, under forced-draft conditions, rose very high.

Discussion of Mr. Weymouth's Paper on Arizona Power Plants Using Oil Fuel

Mr. Weymouth's paper treated of the performances of three steam-electric power plants situated in Arizona where load factor and high fuel cost demand economical operation. These plants are those of the Inspiration Consolidated Copper Company; the New Cornelia Copper Company; and the Arizona Power Company. Tables and curves of operating characteristics were given in Mr. Weymouth's paper and some of the difficulties encountered in practice were also enumerated.

C. H. DELANY[1] (written). The Pacific Gas and Electric Company is operating at Sacramento, Cal., an oil-burning plant which is similar in some respects to the three plants discussed in Mr. Weymouth's paper. This plant was built in 1911 and is equipped with one 5000-kw. Curtiss turbine, Stirling boilers, Peabody-Hammel oil furnaces, and a surface condenser taking water from the Sacramento River. This plant was designed for 175 lb. pressure and 100 deg. superheat at the turbine throttle, and is therefore similar in this respect to the Inspiration Copper Co.'s plant. The plant, however, being essentially a standby plant, is not equipped with economizers, steel casings for the boilers, or automatic fuel-oil regulators.

In comparing the operation of different steam plants operating at variable loads, it is convenient to plot on a diagram the kilowatt-hours generated against the total oil burned, each point plotted representing the average results of a month or a day as the case may be. If a sufficient number of points at different loads is obtained, it is possible to draw a line through them representing their average, and this line in most cases is found to be practically a straight line. Such a diagram for the Sacramento station for the year 1918 is given in Fig. 1, and to it have been added points taken from Mr. Weymouth's paper for the three Arizona plants. The points for the Inspiration Copper Co.'s plant are sufficiently numerous to enable the line AC to be drawn through them, corresponding to the line AB for the Sacramento plant. It will be noted that these two lines intersect the ordinate of zero load at almost the same point, A, indicating about the same quantity of oil (that is, in the neighborhood of

[1] Mechanical Engineer, Ford Motor Co., Detroit, Mich., Mem.Am.Soc.M.E.
[2] President, Sanford Riley Stoker Co., Worcester, Mass. Mem. Am. Soc.M.E.
[3] Vice-President, Solvay Process Co., Syracuse, N. Y.

[1] Pacific Gas & Electric Co., San Francisco, Cal. Mem. Am.Soc.M.E.

25 or 30 bbl. per day) required to operate either plant at no load.

There are not sufficient points to enable a similar line to be drawn for either the New Cornelia Copper Co. or the Arizona Power Co. plants. However, assuming the point *A* for zero load to be the same as for the Inspiration Copper Co., the line *AD* has been drawn as an approximate average for these two plants.

This diagram brings out more clearly than a mere statement of the kilowatt-hours per barrel of oil, though perhaps somewhat crudely, the essential differences between the various plants.

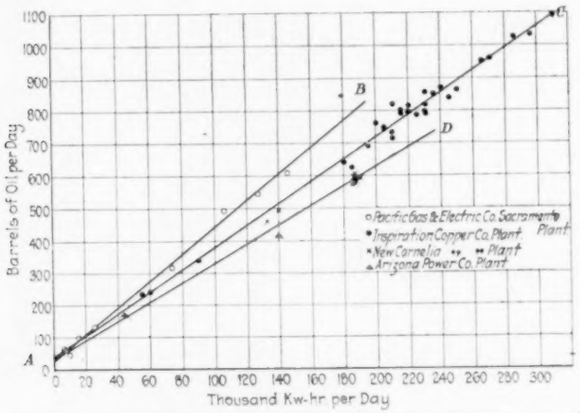

FIG. 1 DIAGRAM SHOWING RELATION BETWEEN BARRELS OF OIL BURNED PER DAY AND KILOWATT-HOURS GENERATED

Thus a comparison of the lines *AD* and *AC* shows at a glance the effect of the higher steam pressure, higher superheat and better vacuum carried at the New Cornelia Copper and Arizona Power Companies' plants. The line *AC* compared with the line *AB* shows the economy resulting from the use of economizers, steel casings, fuel-oil regulators, and other minor differences such as the greater age and smaller size of the turbine in the Sacramento plant.

W. W. JOURDIN[1] (written). Referring to the fourth paragraph of the paper, the Inspiration power plant is equipped with engine-driven circulating units and barometric hotwell, with sealed sump and lift pumps located on a hillside at a sufficient distance below the condensers to secure positive drainage of the condensate therefrom.

The high-pressure cylinders of the blowing engines are being replaced with poppet-valved cylinders good for 250 lb. pressure, and all new equipment, including boilers recently installed, is designed for the higher pressure. However, until such time as the original boilers may be disposed of, a maximum of only 200 lb. pressure will be available at the throttles.

The cooling tower was not put into service until November 1918, therefore the plant operated under the handicap of poor vacuum, due to insufficient cooling capacity, throughout the period covered by the curves given by the author in his Fig. 3.

Figs. 1 and 2 do not represent present practice—in fact, there has been a very considerable departure in numerous operating features from the original instructions, although these in principle were good. Owing to labor troubles, the plant was shut down from July 2 to September 20, 1917, inclusive, and in the absence of detailed explanation concerning conditions, the curves would better be broken between June and October 1917.

The heat recovery is low in the economizers not so much on account of inadequate heating surface as because the recovery by the boilers is so high, compared with coal-burning practice, that little heat available for warming feedwater is contained in the gases to the economizers.

The Inspiration plant is jointly owned by two companies, and the money involved is so large, due to high fuel costs, that it is essential that the measurement of all quantities shall be so made as to secure the highest possible accuracy. The metering equipment is quite elaborate, and the accounting is on the basis of continuous overall plant test; consequently the operators are enabled to check economic performance more closely than is usually possible even in the most highly developed plants.

The economy reported is based on net electrical production, and no deduction is made for fuel consumed in warming up and stand-by due to changes in electrical load.

W. D. ENNIS[1] (written). The maintenance of high overall efficiency in regular operation is a feature to be expected with well-designed plants using oil fuel. In discussing the reasons for the superiority of the New Cornelia plant over the Inspiration the author omits mention of the higher superheat used. Allowing for differences in pressure and superheat, the steam temperatures in the two cases are 471 deg. and 551 deg. The load factor may have been of weight also, but there seems to be nothing in the table dealing with this plant to show whether or not both turbines were running. If they were, the New Cornelia load factor was around 0.50 as compared with a value of about 0.70 for the Inspiration plant.

A most interesting feature of this paper is the indication of maximum boiler efficiency at about 0.60 rating (Fig. 2). The author attributes this to the tightness and insulating efficiency of the sheet-metal casing. It is regrettable that the boiler proportions are not given in some detail. The curve of boiler efficiency against rating cannot be considered a normal curve. The (actual) rate of evaporation at normal rating works out 3.26 lb., or at 60 per cent rating, less than 2 lb.

W. H. BEST[2] (written). There is one particular point to be emphasized in the use of oil fuel in power plants, and that is the importance, wherever possible and wherever plants are of sufficient size, of the company's employing an engineer whose duties will be to see that the oil is properly burned in order that the strictest economy and highest efficiency may be attained and maintained at all times. I have always recommended this in power plants and in forge shops, and I am glad to learn that there is one plant in the United States that really has placed a man in charge, whose duty it is to see that the oil is properly burned. He can save his wages many times by the economy effected in fuel by his attention to his specific duties.

WHY DOES THE WATER IN A BOILER LIFT WHEN THE SAFETY VALVE BLOWS? An editorial written in connection with a recent action of the Boiler Code Committee of The American Society of Mechanical Engineers in regard to the question of safety valves. An attempt is made to answer the question, "What lifts the water from the level of the water line and throws it out of the safety valve?"

When the valve opens the steam rushes out at a rate proportionate to its absolute pressure, resulting in a diminution of pressure in the area immediately below the valve.

When the boiler is steaming, there is, the editor states, no definite water level. The surface is tossing and heaving with the disengagement of steam bubbles. This disengagement will be very active for the first instant that the pressure upon the surface of boiling water is reduced and may be so active right under the valve as to throw up a column of water which, aided by the sweeping action of the steam rushing to the opening with the velocity of a cyclone, is carried out of the boiler.

It is claimed that this lifting action can be avoided by a gradual opening of the valve, the term "gradual" being used in a comparative sense. From this point of view and as far as the relations between the movement of the valve to the lifting of the water are concerned, it appears to be a question more of time operation than of valve lift, and a smaller valve with large lift does not necessarily give a more sudden release. (*Power*, vol. 49, no. 25, June 24, 1919, p. 983, *gt*)

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[1] Chief Engineer, Power Plant, Inspiration Consolidated Copper Co., Miami, Ariz. Mem. Am.Soc.M.E.

[1] Acting Professor of Mechanical Engineering, Columbia University, New York City. Mem. Am.Soc.M.E.

[2] Pres., W. N. Best, Inc., New York City. Mem. Am.Soc.M.E.

The Organization of an Industrial Laboratory

Following This Paper is One on Industrial Research Laboratory Organization, and the Two, with the Discussion at the Research Session of the Spring Meeting, form a Valuable Digest of the Methods and Importance of Industrial Research

By A. D. LITTLE,[1] CAMBRIDGE, MASS., and H. E. HOWE,[2] CAMBRIDGE, MASS.

During the war industrial research in the United States was naturally stimulated, and as a result there now exists a deeper interest than heretofore in the applications of science to manufacturing processes. New laboratories will undoubtedly be built and many old ones reorganized in order to render more efficient service. It is the purpose of this paper to point out the organization and conduct of such a research laboratory.

The authors first outline the aims of a research organization, following which the divisions of the laboratory are enumerated and discussed, the laboratories of Arthur D. Little, Inc., being taken as a type. The methods of management, writing of reports and the commercial organization of the laboratory are also discussed at some length, and the paper concludes with a description of the building and equipment best suited to carry on this type of work.

PREVIOUS to the war there were about 375 industrial research laboratories in the United States, including those maintained by manufacturers for their own benefit, and commercial laboratories prepared to render similar service. At the present time there are no figures available regarding the number of new laboratories established as a result of the war, but there is no doubt but that the war created a deeper interest in industrial research, and the application of science to manufacturing processes. It is also evident that those laboratories which existed before the war are displaying a greater interest in fundamental research, and in rehabilitating their organizations are paying far more attention to the research phases of their problems than they have been willing to do heretofore.

In discussing the industrial laboratory we may choose between the one organized for the purpose of exploring some small corner of the broad field symbolic of our ignorance and an establishment concerned with the greatest variety of problems. A laboratory of the latter type should consist of a collection of special laboratories carefully articulated to produce results most efficiently, and the work common to all of them should be organized separately in a large general laboratory. Fortunately for our country there are several such laboratories doing splendid work, and notwithstanding the care exercised to avoid undue specialization, nearly all of them contain departments which dominate, due either to stronger men or the greater appeal which these departments make to the company; or perhaps to a seemingly greater importance of their class of problems at the moment. The great majority of these laboratories are maintained in the plants of industry at an annual expense running up to two millions in at least one case, and with many spending hundreds of thousands each year.

Another plan which should be mentioned involves the training of men as a primary consideration, and the Mellon Institute, at Pittsburgh, affords a conspicuously successful example of what may be done in educational institutions in solving the problems of industry, while at the same time men are trained in research.

The Aims of a Research Organization

Broadly stated, the aims of a research organization should be:

a To find, develop and train men

b To create such a background in the public mind as shall insure support for research and the industrial utilization of research results

c To secure coöperation between different branches of science, as, for example, between chemists and mathematicians

d To avoid repetition and duplication of effort, first by rendering present knowledge readily available to research workers, second by applying clearing-house methods to research projects

e To stimulate research by emphasizing the importance of specific problems, making special grants, rendering material and facilities as generally available as possible.

f To furnish a general staff for research which shall work out the plan of attack for major problems, assign the several lines to competent workers and coördinate and focus the whole

g To bring home to manufacturers the advantages of research with the view of promoting the establishment of private, corporation, and group laboratories

h To make and publish a census of available research facilities in men and equipment

i To survey the natural resources of the nation and direct research toward their development

j To appraise our great industrial wastes and develop plans and methods for turning them to profitable use.

As regards any research laboratory, it goes without saying that it is the personal factor which determines performance and this is preëminently true of the laboratory director. Sir Humphrey Davy truly said that his greatest discovery was Michael Faraday, and no greater problem is likely to confront a research laboratory than that involved in the discovery of a director. Successful laboratory directors may be of several types, but a militant optimism, contagious enthusiasm, controlled imagination and quick human sympathy are common to them all. Such a man will naturally in selecting his subordinates look for these personal qualities almost as carefully as he will weigh specialized scientific training, and having been thus guided in his selections will find it relatively easy to inspire throughout his organization those relations of good fellowship and that *esprit de corps* which multiply enormously the effectiveness of any working force.

The so-called commercial laboratory devoting its efforts to industrial research and operated on a strictly business basis will best serve our present purpose, and that of Arthur D. Little, Inc., in Cambridge, Mass., will be taken as a type in the belief that much of interest will be found in this establishment, which is "dedicated to industrial progress." During the past thirty-three years this laboratory has grown from a partnership of two chemists to an organization of sixty people, and scheme after scheme has been devised for the management of the enterprise, only to find new conditions and rapid growth calling for constant revision. Being a corporation, it is managed by the usual officers with a board of directors, all of whom do not devote their entire time to the business.

The Divisions of the Laboratory

Within such a laboratory there are two distinct sets of duties which may be designated as scientific or technical, and commercial or financial. These two divisions have at least two points in contact, one being through a service manager, and the other the department charged with obtaining new business for the organization.

Presented at the Spring Meeting, Detroit, Mich., June, 1919, of The American Society of Mechanical Engineers. The paper is here printed in abstract form and is subject to revision. Copies of the complete paper may be obtained at a nominal cost.

[1] President, Arthur D. Little, Inc., Mem. Am. Soc. M.E.

[2] With Arthur D. Little, Inc.

The fundamental duty of the scientific division is to interpret the results of pure science in the terms of industry. While the work of the commercial laboratory is of the same order as that done in any laboratory even where the dollar is never discussed, it must be conducted with full recognition of the fact that many industrial problems are as intimately concerned with economic questions as with scientific. In other words, while for instance a laboratory process in glass may be intensely interesting and of fundamental importance, the client can hardly be expected to be satisfied with a report unless a commercial method for operating it can be devised. The technical work should be in charge of the president, under whom various departments should be organized, so that each phase of a given problem may have the attention of a specialist, provided with adequate equipment to facilitate the work.

In this connection it may be emphasized that it pays to provide congenial, inspiring surroundings for the laboratory worker. The laboratory can be made attractive without being ornate, or involving unreasonable expense, and every effort should be made to have the workers reasonably happy. Under no other condition can the best work be expected, and it must be remembered that the heaviest investment is in the time of these workers, the salary cost being much greater than that for equipment or material maintenance. Rewards other than monetary for faithful service also play an important part.

The departments into which the technical division are divided will naturally differ in each laboratory, but a fairly definite line can be drawn between research, engineering and standardized or routine work. It is advantageous to have all of the standardized work, including that incident to research and engineering, carried on under one department head, for in this way it can be done to better advantage both as regards efficiency and economy.

The research department should be organized for both laboratory and small-factory-scale work. There will be a multiplicity of subjects, and since special facilities cannot be provided in advance of close acquaintance with the problem, the organization of departments for research along special lines will concern personnel more than a division of floor space or equipment.

Engineering will embody plant inspection, design, construction and operation, and although much of its work will be in the field, many phases of its problems will be worked upon concurrently in the laboratory.

The analytical department will be subdivided under such headings as textiles, fuels, food, metallurgy and metallography, chemical microscopy, water, lubricants, construction materials, pulp and paper, fermentology, etc. Some of these subjects will require special accommodations, while others can share a large laboratory which provides space for certain apparatus kept in place for a large number of similar determinations.

Nothing is more expensive or demoralizing than experimentation in the plant. An industrial research laboratory should therefore be adequately provided with equipment of semi-commercial size. Infant mortality among processes is high in any case and the most critical period in their young lives is that covering the transition from the laboratory to the plant. They require and the research laboratory should provide a nursery to protect and foster them during this period of their development. Some large manufacturers have even found it desirable to operate in connection with and under the sole direction of their research laboratory a small plant in which actual commercial manufacture is regularly conducted. Such extension of the laboratory's function permits the complete reduction to practice of new methods and the commercial demonstration of the sufficiency of the product before the innovations are introduced into the main plant.

Even when no such provision appears feasible, it is, nevertheless, highly desirable to have the industrial research laboratory actually engaged in some small scale, highly specialized, commercial manufacture, preferably of some product which it has itself originated. The least advantage of this procedure is that such manufacture of a properly selected product may frequently defray a substantial proportion of the expenses of the laboratory. The major benefits are the acquirement of a certain commercial sense by the laboratory staff, an appreciation of the conditions and difficulties of actual production, and finally the strengthening of the position of the laboratory through the increase in its turnover and equipment.

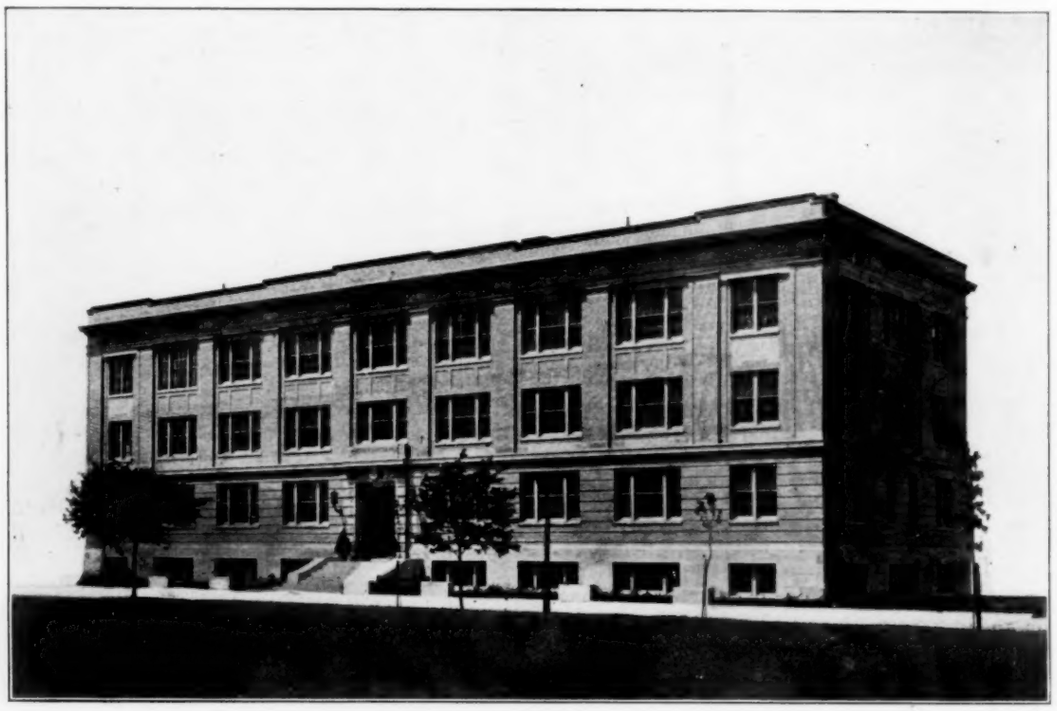


FIG. 1 THE LABORATORY OF ARTHUR D. LITTLE, INC.

The Method of Management

It is easy to visualize the organization chart for such a laboratory, and a brief description of how a new piece of work will be handled may therefore convey a better idea of the method of management. The authorization for the work will go to the service manager, who sees all incoming mail, and to the authorization will be attached any correspondence or data bearing on the case, all of which will be given a case number for identification, and this number will be entered in a case register, which will indicate the name of the client, the subject of the problem, the date the authorization is received and the date when the work shall have been completed. The service manager, who must be familiar with the ability of each member of the staff, as well as with the work in hand, will assign the case to the division which can render the best service. Conferences will then be called, into which any member of the organization who can contribute anything to the solution of the problem in hand will be drawn, and outside associates or independent consultants may be included. The problem will then go into work by means of instruction sheets, setting forth what is to be accomplished, suggesting methods of attack, relating any special circumstances, references to literature, and standard methods which may be applicable, and as much light as possible given to the individual who is to do the work. Accompanying the case there will be a tag bearing the case number and upon it a date at which it is expected the work can be completed, or a progress report made, must be indicated. The tag is then returned to the service manager. Through the means of data sheets, time slips and verbal reports the progress of the problem will be readily followed. This procedure will be followed in all the divisions, the individual reporting to his superior, and the service manager will be alert to insure prompt and efficient service to all clients.

At the completion of the work the report, varying in extent from a single printed form to a bound volume of several hundred pages, will pass through the hands of all concerned, and will thus be distinctly the report of the organization and not of an individual in the organization.

Reports

Writing a report requires skill, for it must be comprehensive. It should begin with a clear statement of the problem, followed by the conclusion reached as a result of the work, which may then be described in detail. Patents, cost data, tables, graphs, photographs and samples should be dealt with in an appendix, and in some instances descriptions of apparatus should be included. The whole must be carefully indexed, and a copy sent to the library to be bound and kept as confidential information in locked cases, but as part of the library it should be carded for the library card index. Obviously no fast rule can be laid down for writing reports, but it should be borne in mind that many of those who read technical reports are not interested in minute details, and that the subject-matter must be presented in a form that will be interesting and understood by the layman. It must also have its important points so emphasized that they can be readily picked out by those not caring to read the entire report, but at the same time it should include sufficient data to serve the purpose of a fully qualified technical man to whom the report may be referred at some later time.

This brings up the question of the library, which may easily be considered the backbone of the industrial laboratory. Its extent will depend upon other library material available in the community but there are few things which obstruct research more seriously than the absence of easily accessible proper library facilities. A few dollars spent in books and literature frequently saves as many hundreds otherwise spent in work of duplication. The useful periodicals must be provided, elaborate indexes will be found a good investment, also abstracts and patents; in short, every means for quickly locating literature references should be at hand. The current literature, with articles of interest indicated on an attached slip, should be circulated among the members of the staff whose names are checked on this slip, and some one, preferably a chemist, should have assigned to him the task of constantly reading the literature in order that no scrap of information shall escape. Such a chemist-librarian will conduct searches in other libraries, prepare abstracts, and in fact direct

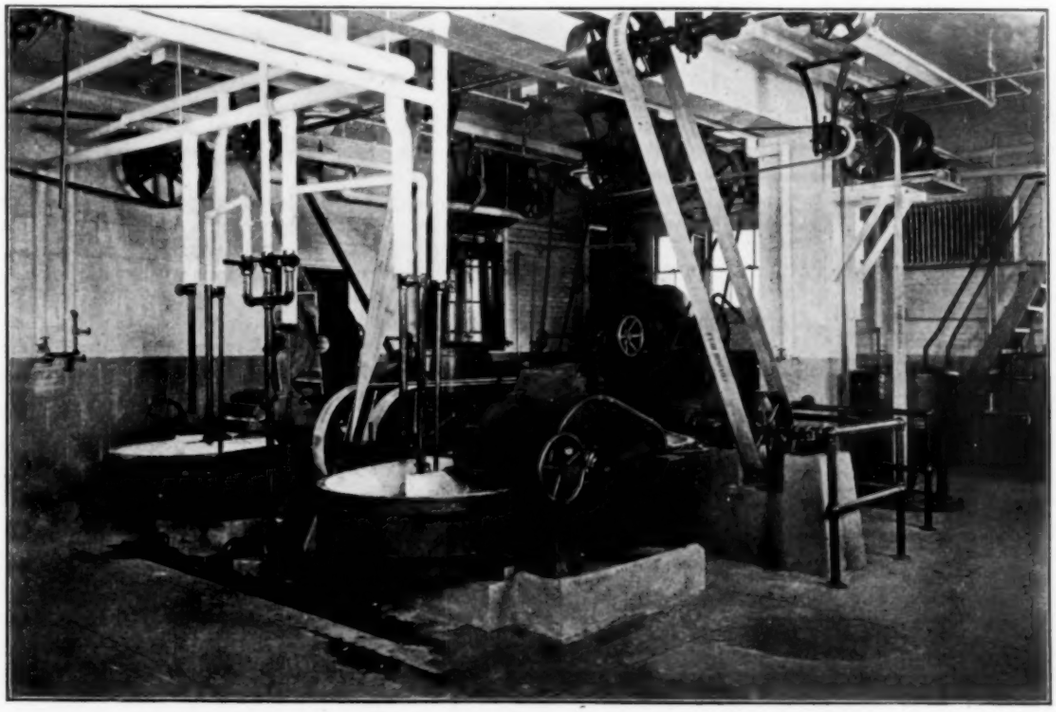


Fig. 2 Experimental Paper Mill, Laboratory of Arthur D. Little, Inc.

the information service for the laboratory, and through the laboratory to its clients.

BUILDINGS AND EQUIPMENT.

With this general plan of management before us, we may now consider the equipment and space required for effective work.

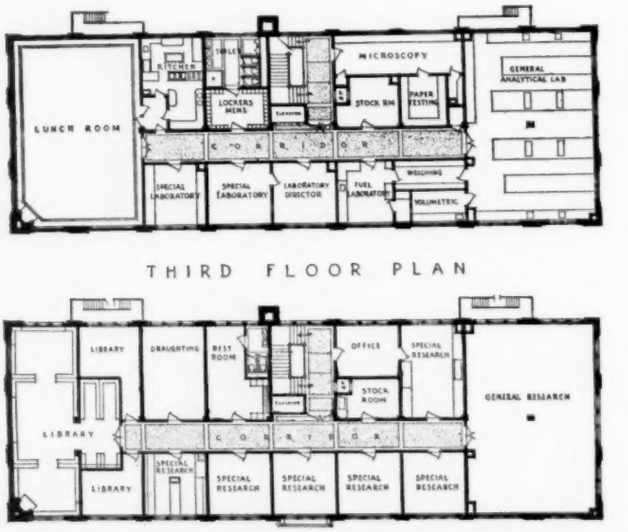


FIG. 3 PLANS OF THE LABORATORY OF ARTHUR D. LITTLE, INC.

Experience has shown that a satisfactory building is one approximately 50 ft. by 150 ft. (planned so that another building may be easily connected in H-formation) and consisting of a basement, with three floors, the basement itself being so designed that it is as light and airy as the upper floors. Such a building with a wing housing the power plant and small grinding rooms (this being the connected wing of the H) has a total floor space of approximately 30,000 sq. ft. The building occupied by Arthur D. Little, Inc., is of this type and the various departments are allotted the following space: Analytical division, 5328 sq. ft.; research division, 3458 sq. ft.; engineering, 1155 sq. ft.; commercial department, 768 sq. ft.; management (meaning the management of outside enterprises), 538 sq. ft.; special department devoted to pulp and paper, 4118 sq. ft. The portions of the building which are non-producing, such as miscellaneous offices, which includes stairs, corridors, halls, lavatories, etc., comprise 8000 sq. ft., and the space unassigned amounts to 3815 sq. ft. This includes laboratory space provided for emergencies and expansion but not in constant use.

These area measurements form the basis of apportioning overhead due to interest on investment, depreciation, repairs, insurance, upkeep, etc., and among the departments is distributed the charge for carrying 768 sq. ft. devoted to an industrial museum and 1536 sq. ft. devoted to the library.

The basement will provide room for the power plant, the current sample room, the general stock room, two very large rooms for small-factory-scale equipment, two small rooms for coal and other crushing and grinding operations, and a machine shop in which the physical testing machinery can be installed. A laboratory for testing construction materials, such as cement, may also be placed in the basement to advantage, and here, too, a room and vault can be set aside for inactive letter files and records.

The first floor will provide a series of offices each of about 250 sq. ft. area, two larger ones which may be used by officers of the company, consulting engineers and others, a reception room, and an information booth with switchboard. The museum can also be on the first floor, together with the rooms devoted to the commercial department's work. Quarters for the financial division, with ample vault space, and room for current correspondence and the general stenographers' office complete the floor. The engineering division might also occupy rooms on the first floor.

The second floor may be properly devoted to research and the library. It is frequently advantageous to be able to segregate research problems, and it will be well to provide a series of small rooms, say of approximately 250 sq. ft. in area, which can be fitted up in accordance with the requirements of the problem, and easily dismantled at the conclusion of the work, to be refitted according to the next undertaking. A branch stock room should be located on the second as well as the third floor, and these should be served by elevator from the general storeroom in the basement. There are always a number of scattering problems in research that can be handled in one laboratory, and so a special-problems laboratory should also be provided on the second floor with an office for consultation purposes. Finally a large room, say of 1500 sq. ft., should also be available for large undertakings, and as a space for emergency overflow.

The third floor may comprise the general analytical laboratory, a room of about 1500 sq. ft., adjacent to which should be a room for titration and the balance room (each of approximately 125 sq. ft.), a fuel-testing room and a special room for extraction. A branch stockroom and the offices of the head chemist and assistants should also be on this floor. The optical room should be placed where north light can be obtained, and a small dark room must be provided, as well as a specially equipped room for the physical testing of paper and textiles. The kitchen can adjoin the assembly room. A locker room for the men and a rest room for the women must also be provided. Space under the roof can be used for fans and a ventilating appliance, water tanks, etc.

Such a building as has been thus briefly described will cost about $200,000 and $50,000 will provide general equipment. There is always something new to buy for a laboratory. Such an establishment will provide working space for approximately 150 people, and more could be accommodated if necessary, depending largely on the type of work being conducted. The cost of operation and maintenance, based on a staff of sixty, will be about $20,000 per month.

Industrial Research Laboratory Organization

By K. C. MEES,[1] ROCHESTER, N. Y.

The great value of scientific research, both to the industries and the nation at large, is now generally recognized. The industrial research laboratory is an important factor in maintaining the supremacy of an industry, and its success depends to a considerable degree upon its relation to the other departments of the company with which it is associated. In this paper these statements are discussed, and the author presents his views regarding the establishment and function of industrial laboratories, giving in connection with the latter three annular diagrams. The form and operating costs of industrial laboratories are also discussed.

THE triumphs which have already been won by research laboratories are common knowledge. The incandescent-lamp industry, for instance, originated in the United States with the carbon-filament lamp, but was nearly lost to this country when the tungsten-filament was developed, only to be rescued from that danger by the research laboratory of the General Electric Company, who fought for the prize in sight and developed first the drawn-wire filament and then the nitrogen lamp; and we may be sure that if the theoretical and practical work of the research laboratory of the General Electric Company were not kept up, the American manufacturers could by no means rest secure in their industry, as, undoubtedly, later developments in electric lighting will come and the industry might be transferred, in part if not completely, to the originators of any improvement. Manufacturing concerns and especially the powerful, well-organized companies who are the leaders of industry can, of course, retain their leadership for a number of years against smaller and less completely organized competitors, but eventually they can insure their position only by having in their employ men who are competent to keep in touch with and to advance the subject, and the maintenance of a laboratory staffed by such men is a final insurance against eventual loss of the control of its industry by any concern.

The success of an industrial research laboratory depends to a considerable extent upon its position in the organization and upon its relation to the other departments of the company with which it is associated.

If industrial enterprises had been organized afresh with the research laboratory as a definite part of the organization, it is probable that by this time some general opinion would have been formed as to the position which the laboratory should occupy, but in fact nearly all industrial research laboratories have been added to organizations already formed, and their relations to the other departments of the organization are usually closely associated with their origin.

Laboratories are established in many different ways. If there is a technical scientific expert in the executive of the manufacturing company he may feel the need of a laboratory and become its director, and in this case the laboratory will necessarily be very closely associated with the work of the executive who initiated it.

A laboratory may also be established under a separate director, not himself associated with the executive officers of the company, but as a reference department for the executives, and in this case also it will be very closely associated with the officers of the company and will tend to be concerned more with questions of policy and the introduction of new products than with any other of the problems of the company.

In a large company a research laboratory may be established as a separate department, having its own organization and being available as a reference department for all sections of the company, in which case its activities will cover a very wide field, but at the same time it will not have as direct an influence upon the policy of the company as will happen if it is closely associated with one or more of the executive officers.

The earliest research laboratories grew out of the works testing and control laboratories and were therefore responsible directly to the works manager. More recently, laboratories have generally been established as independent departments of the company and responsible only to the general manager.

The executive official to whom the laboratory should report will depend upon the nature of the work to be done. There may be industries in which research work is required for only a single department, and in this case the research workers should be responsible to the head of that department; there are others in which the interest in the research is confined to the works, and in such cases the laboratory should be responsible to the works manager; but in most technical industries research work will have a great bearing not only on the methods of production but even on the general policy of the industry, and in such cases it is necessary that those who direct research should be in touch with, and responsible to, the executives who control policy.

The position of the research laboratory in an industrial organization is perhaps best determined by the criterion that the research department should be responsible to the officer of the company who is in charge of the development of new products. If the introduction of new products is in the hands of the works organization, then the research department should be responsible to the works manager; if there is a definite development department, or, if new products are introduced through the agency of some definite executive, then it is to that executive that the research department should be responsible. The research laboratory, in fact, should primarily be associated with development.

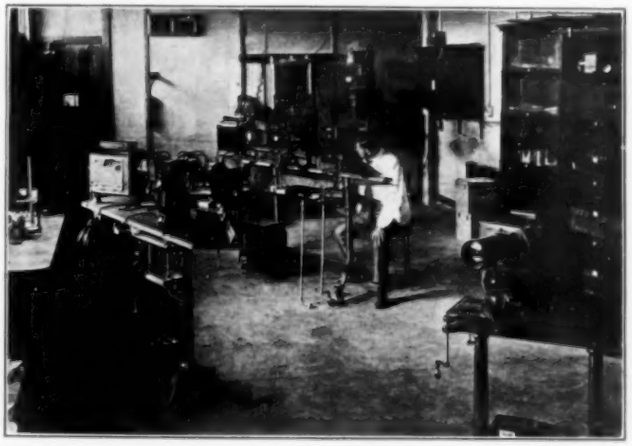


FIG. 1 A LABORATORY OF THE EASTMAN-KODAK COMPANY

The chief functions of the laboratory are as follows:

1 The provision of information regarding the technical and scientific matter in which the industry is interested, and the supply of this information in a form suitable for the education of the employees, of the customers, and of the general public.

2 Service in the form of the provision of specifications and standards for materials, the making of analyses and tests, assistance to the works in regard to difficulties and to customers in the relation of problems arising from the use of the product.

3 The development of new processes or products, utilization of by-products, the development of new departments of the industry.

These functions may be expressed by means of annular diagrams such as those shown in Figs. 1, 2 and 3. Fig. 1 shows

Presented at the Spring Meeting, Detroit, Mich., June, 1919, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. The paper is here printed in abstract form and is subject to revision. Copies of the complete paper may be obtained at a nominal cost.

[1] Director of the Research Laboratory of Eastman-Kodak Company, Rochester, N. Y.

the information diagram. The information originating from the library and from the research staff is issued in the form of abstracts, reports, scientific publications and monographs, and first goes to the executive, manufacturing, purchasing and sales departments for their information; then to the advertising and educational departments to be placed in the form required for publication in the scientific and general press.

The organization of the development work is shown in Fig. 2, where the work is shown to be founded upon pure research done in the scientific department, which undertakes the necessary practical research on new products or processes as long as they are on the laboratory scale, and then transfers the work to special development departments to form an intermediate stage between the laboratory and the manufacturing departments. These development departments are really small scale manufacturing departments which may be operated either by the works department or by the laboratory; but which are controlled, as regards the work done in them and the method used, by the laboratory itself, being run as experimental departments in order to develop a new process or product to the stage where it is ready for large scale manufacture.

In Fig. 3 the service diagram shows the scientific divisions as the operating center, each of which supports and controls the necessary service departments which prepare specifications and standards, undertake testing and analysis, the investigation of works troubles, complaints of customers, and suggestions from the sales department, the results of which are communicated to the departments interested.

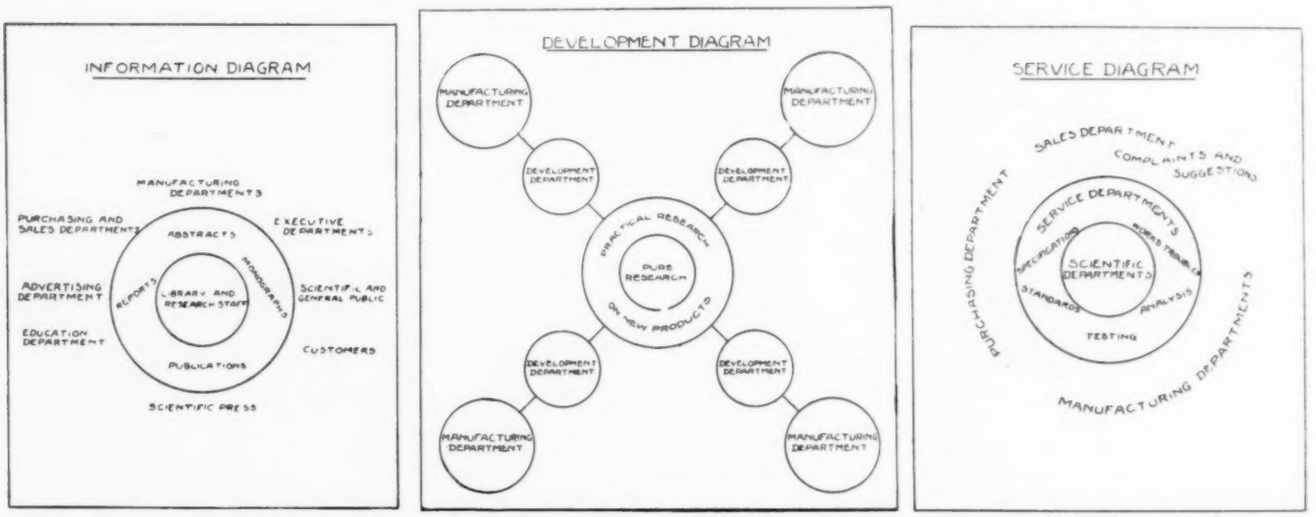
The laboratory organization will therefore consist of a section of administration, which will be responsible for the direction of the work, the control of accounts and the issuing of reports; a section of information, which will operate the library, prepare abstracts of the literature, keep in relation with the patent department and constitute its technical wing, and prepare reports and publications of all kinds; and the scientific section, which will carry on the operation of the laboratory work.

There are two forms of organization possible for the scientific work of the laboratory. For brevity these may be spoken of as the "divisional" system and the "cell" system. In the divisional system the organization is that familiar to most businesses. The work of the laboratory is classified into several divisions; physics, chemistry, engineering, and so on, according to the number necessary to cover the field, and each of these divisions has a man of suitable scientific attainments in charge of it. In a large division each of these men will in turn have assistants responsible for sections of the department, all the heads of divisions finally being responsible to the director of the laboratory.

Under the alternative or cell system the laboratory consists of a number of investigators of approximately equal standing in the laboratory, each of them responsible only to the director, and each of them engaged upon some specific research. Each such investigator, of course, may be provided with assistants as may be necessary.

In practice, some system between these two systems of organization is essential and will develop in any laboratory. It is not possible to work a rigid divisional system, and on the other hand no cell system in its most definite form could be effective.

The scientific work of the research laboratory is best directed by means of a conference or series of conferences of all the men having knowledge of the subject, and this will have the further advantage that, while it will relieve the director of the details of the direction of the scientific work, it will keep him constantly informed as to all the work going on in the laboratory.



FIGS. 1, 2, 3 DIAGRAMS ILLUSTRATING THE FUNCTIONS OF AN INDUSTRIAL RESEARCH LABORATORY

From various sources, but chiefly from the convenient list of American laboratories given by Fleming there can be found the cost of a research laboratory per scientific worker employed. It might seem that there would be very great variations in this, but, provided that the laboratories are all of the physical and chemical type, there is a surprising agreement between the figures, which show that the cost of building and equipment for a laboratory will be between $3000 and $4000 per man. From the same sources the annual cost of maintenance of such a research laboratory appears to be slightly lower than the first cost. Probably $3500 per man will be a fair estimate of the cost of maintenance, and of this we may take 60 per cent as representing salaries and wages and the remainder all other expenses.

As laboratories are organized and experience gained in the types of laboratory suitable for different industries it will doubtless be possible to lay out definite schemes of organization for a laboratory suitable for the requirements of any industrial undertaking. At the present time, however, it is possible to do this only in the most general way, and it is necessary to consider each case independently, taking into consideration the requirements of the particular industry involved.

Fortunately data on this subject are being accumulated at the present time and the whole question of laboratory organization is being studied carefully both here and abroad. In this country the National Research Council has appointed a special committee to promote industrial scientific research and this body is now engaged in drawing up a scheme for the establishment of an alloys research laboratory and is considering other lines of industrial research all of which I am sure will meet with the approval and support of The American Society of Mechanical Engineers.

DISCUSSION AT RESEARCH SESSION OF SPRING MEETING

THE Spring Meeting of the A. S. M. E., held at Detroit, June 16 to 19, devoted its second session to a consideration of the status of research in this country. Four papers and an address were delivered. Those by Arthur M. Greene, Jr., on The Present Condition of Research in the United States, by Enrique Touceda, on Research Work on Malleable Iron, and by G. H. Clevenger, on The Division of Engineering of the National Research Council, appeared in abstract form in MECHANICAL ENGINEERING for July and in this issue the remaining two are presented. One of these, by Arthur D. Little and H. E. Howe, is on The Organization of an Industrial Laboratory, and the other, by Dr. C. K. Mees, deals with The Organization of a Research Laboratory. Abstracts of the discussion of these various papers follow and it is not surprising to find that opinions regarding the value of research vary but little, for it is unquestionably true that research is rapidly coming into its own and bids fair to occupy to a considerable extent the attention of the industrial world.

P. F. WALKER[1] (written). The author has truly said that in most of our educational institutions the members of the faculty are so burdened with routine teaching that large amounts of research work cannot be expected. There is good reason, however, why the schools need to give active attention to scientific investigation. It is the schools that must produce the men to go into active professional work, including research. In the schools these men have implanted in them certain ideals which will remain, perhaps unconsciously, as determining factors in their lives. To promote research is therefore of vital importance in order that the students should be brought face to face with research problems, and thus imbibe something of the spirit of the investigator.

A matter in which the writer is at present personally interested and to which he is giving a great deal of attention is the state industrial problem. It is a research side of that new branch of the profession sometimes designated as industrial or commercial engineering. Every state and every community has problems peculiar to itself and it is a function of state educational institutions as well as of the engineering profession to interest themselves in such problems with the aim of rendering service. A combined survey and study of industrial possibilities is being made. This is mentioned here because it is a kind of research not always thought of as coming within the scope of the engineer. To the writer, however, it seems that it is an activity which comes distinctly within the terms of that definition which states that engineering is the application of all of the sources of power to the use and convenience of man. In any community, and particularly in one where the natural resources are not yet developed by industries to the full extent that economic conditions will warrant, it is the business of the engineer to encourage and pave the way for new industrial development as truly as it is to develop the natural agencies for its successful prosecution.

F. J. SCHLINK[2] (written). The importance of real research work and its possibilities in returning a quite extraordinary profit for a very moderate expenditure, cannot be overemphasized. If this end is to be attained, however, the venture must be undertaken with a broad vision and the investigator must be permitted within reasonable limits to carry on studies which may not promise immediate pecuniary benefits.

It is nothing less than astonishing to find, as we occasionally do, that a long-established product, supposedly fully standardized, is being manufactured without even a superficial knowledge of the simple engineering and scientific facts that underlie its performance. Some of the portable or hand-operated fire extinguishers are splendid examples of this class, and in these simple devices, which are not nearly so complex, from the designing and manufacturing standpoint, as an alarm clock or a lawn mower, the varied and manifest types of mechanical and operating failures presented are well-nigh unbelievable. One can say with a high degree of certainty that the expenditure of $500 in a real engineering study of the problems of materials and function in any one of several such extinguishers would have made unnecessary the waste of many thousands of dollars in ineffective designs, some of which are absolutely a menace in that they give the user a false and unfounded sense of security against fire hazards.

The condition of American business in which large profits could be made without the necessity of careful and rigorous attention to engineering research and standardization, is rapidly passing away in the face of the present perplexing industrial situation. The advancing costs of labor and material with the concurrent unwillingness of the public to pay increased prices for the manufactured product it consumes, are bringing to every manufacturer a problem of almost crucial character, of holding down or reducing his manufacturing costs without depreciating his product. This difficulty must be met on the one front by research and standardization, and on the other by the efficient management of labor; and the former, though not so well advertised or perhaps even so highly regarded, is likely to prove at least as powerful an ally as the latter.

ARTHUR J. WOOD[1] (written). In his paper, the author states that one of the great needs of the present time is for research men and then follows this with a statement which in itself explains why there are not more men available. He says, "The love of the work will prove to be the incentive as in many cases the monetary returns are small." I believe that the author is conservative in saying "many cases,"—it should read "most cases."

Monetary returns will never make a research engineer out of one whom nature never fashioned for such work, but it will produce results of unmeasured value from the one who has the love of and ability for research work if it frees him from financial cares which he otherwise must carry.

Surely the need is for more research men and the industrial laboratories look primarily to the colleges for their material, but what are the colleges, as a whole, doing to develop men along these lines?

In the period of awakening to the value of research there will be plunges into subjects without proper preparation or preliminary study and analysis and some half-baked results of tests will doubtless be put forth as research, partly because the colleges cannot or do not pay salaries to teachers and investigators which would train the right men in the proper lines. The making of a research worker is a long-time process, and it calls for a normal, straight-thinking mind, well informed and evenly balanced, which must be left free to get results. One of the apparent needs for men in collegiate research is for more leisure in which to think out methods, to plan work in fields not already well occupied and to keep the mind thoroughly saturated with the subject at hand. How much leisure should be granted? The man himself should be the one best qualified to answer this.

Regarding industrial vs. pure research, there should be no conflict; no line of demarcation can be drawn between the two although they are essentially different. One is helpless without the other. No research is so "pure" but that it may some day lead to results of commercial value. It is unfortunate that many engineers do not have a true conception or an adequate appreciation of the value of scientific research.

The Society through its Committee on Research and the various sub-committees, may also be an important factor in guiding the pioneer work. It may help to raise the standards of pure research so that industrial and educational institutions alike will accept the definition of research as given by the late Dr. R. H. Thurston as "the art of revelation and prophecy." The Society must be a leader in the great work and place research in its accepted and well-deserved place among engineering enterprises.

[1] Dean, Schol of Engineering, Lawrence, Kan. Mem. Am.Soc.M.E.
[2] Associate Physicist, Bureau of Standards, Washington, D. C. Jun. Am.Soc.M.E.

[1] Professor of Mechanical Engineering, Pennsylvania State College. Mem. Am.Soc.M.E.

H. S. COLEMAN.[1] The system of research at the Mellon Institute was formulated by the late Robert Kennedy Duncan and placed in experimental operation at the University of Kansas in 1906. In 1911 the system was inaugurated at the University of Pittsburgh, and in 1913 established on a permanent basis there through a gift, by Messrs. Andrew William and Richard Beatty Mellon, bankers of Pittsburgh, of a modern research building and an endowment to cover the general overhead expenses and salaries of the administrative staff.

Any company or association of manufacturers having a problem or group of problems requiring investigation may become the donor of an industrial fellowship by contributing to the Mellon Institute a definite amount of money, for a period of not less than one year. This foundation sum must be adequate for the purchase of all necessary special apparatus or other equipment as well as to furnish the annual stipend of the research man or men selected to work on the particular problem. The Institute houses the investigatory work, furnishes it with the use of its permanent equipment, affords library and consultative facilities, gives careful direction to the progress of the research, and provides an atmosphere which is conducive to productive inquiry. All results obtained during the course of the industrial fellowship belong exclusively to the donor.

The institute is not, in any sense of the word, a commercial institution, being entirely independent and deriving no financial profit from any investigation conducted under its auspices. In fact, during the last fiscal year, it was necessary to draw upon the endowment fund for almost $70,000.

Up to the present time the engineering research carried on at the Mellon Institute has been rather limited in scope as the present building and equipment were designed mainly for chemical research. There are, however, three fellowships at present in operation involving engineering research, and plans are now under way for the construction of an engineering research building which will provide adequate facilities for extensive engineering investigation.

Investigations are usually worked out in three stages. First, there is the laboratory stage; then comes the unit plant or semi-commercial stage and finally the process is placed on a commercial basis in the plant of the donor. The fellow who has developed the process through the laboratory and unit-plant stages is usually at this time taken over by the company and placed in direct charge of the new process.

As a result of the investigations involving the development of new processes, a large and valuable collection of special equipment has been acquired. This equipment, in most cases, becomes the property of the Institute at the expiration of the fellowship for which it was purchased, and is available for further use in connection with new problems.

JOHN R. ALLEN.[2] About a year ago, the American Society of Heating and Ventilating Engineers decided to establish a research laboratory, and the committee in charge of the work decided to associate themselves with the Bureau of Mines, as the Bureau agreed to provide the necessary laboratory space.

The funds that have been provided for the laboratory have come largely from manufacturers and others interested in the work; although the work in general will not be of a commercial nature but rather of a fundamental character. With that consideration in view the committee has laid down three principal activities for the institution: first, the obtaining of data covering the subject of heating and ventilating; second, the establishment of standards for the use of heating and ventilating engineers; and third, the work of research.

The work of research has been divided into two departments, one to be conducted at Pittsburgh and the other at the mines. Many of the laboratories in this country that are doing research work along the lines of heating and ventilating can materially assist our laboratory and thus the work of acquiring information on the subject of heating and ventilating can be accelerated. In the Bureau of Mines itself the principal work to be done is in connection with the subject of ventilation as this is one of the most difficult questions to be considered.

ZAY JEFFRIES.[1] The Aluminum Castings Co. is engaged in a line of endeavor which for a long time has been determined by research that has been largely limited to the more refined methods of production. As a parallel to our line of work, the American Smelting Refining Company's method of research is something, which while it might not be termed research in an ordinary concern, is nevertheless very highly specialized. They examine a great many prospects and I believe in a certain three-year period, ending about 1916, they had examined about 900. At that time they had selected three for purchase and further development. That is a type of research work that one does not ordinarily come upon, but it nevertheless is considered essential for their business.

The Aluminum Casting Company's laboratory employs between 80 and 90 individuals. It is a two-story building 50 x 230 ft.; and its equipment is valued at approximately $150,000. The annual expenditure for this work alone, is about $300,000. We are finding out a great many things in connection with the non-ferrous alloys, but we have only advanced far enough to begin to apply these fundamentals to our industry. Our work is new, and yet its application is even now finding itself here, and no doubt will find its way further in the future.

CHARLES RUSS RICHARDS.[2] Some 25 odd years ago the first effort was made to provide for congressional action in engineering experiment stations, but for one reason or another the efforts to secure action of Congress were futile. A few years later the officers of the College of Engineering, University of Illinois, succeeding in interesting their board of trustees in engineering research, and in December 1903, the Engineering Experiment Station was organized and it has since undertaken, in a rather systematic fashion, the conduct of research in a great variety of lines. This is an organization within the college of engineering. Each member of the faculty is encouraged to devote any time he may have at his disposal to conduct research work. If he has a good problem which he wishes to undertake, we undertake to relieve him of exacting teaching or administrative duties, to permit him to give time to the work. The principal portion of our work, however, is carried on by the research corps, which is composed of various full-time and a number of part-time students.

In addition to the work which we are doing in research, there have been from time to time coöperative investigations of problems undertaken at the direct request of an industry or group of industries. At the present time there are at least four or five such investigations in progress.

As a state institution it becomes essential for us to safeguard the work which we do and in all of our coöperative investigations we reserve absolute proprietorship in the results obtained and the rights to publish them.

The Engineering Experiment Station now expends approximately $50,000, but as this must be divided among nine or ten different departments, it thus gives only a small sum to each. It is my hope that each one of our men who is a specialist in his particular line may have the opportunity to direct a special corps of investigators, thus developing scientific knowledge to a point where it would be helpful to industries, and through the accumulation of large sums of money, enabling us to do work on a scale which is not possible for any college, no matter how magnificent that may be. If I can secure the coöperation of the industries of Illinois, I have little doubt but that it will be accomplished.

CHARLES H. BENJAMIN.[3] The Engineering experiment station at Purdue is an infant but two years old, but it is a very lusty infant, alive and kicking. We now have a paid staff of workers, and a very good field in which to work, and our future is still before us. Our object in establishing the station was primarily to

[1] Asst. Director, Mellon Institute of Industrial Research, Pittsburgh, Pa. Mem. Am.Soc.M.E.

[2] Dean, College of Engineering and Architecture, University of Minnesota, Minneapolis. Mem. Am.Soc.M.E.

[1] Director of Research Laboratory, Aluminum Castings Co., Cleveland, Ohio.

[2] Dean, College of Engineering, University of Illinois, Urbana, Ill., Mem. Am.Soc.M.E.

[3] Dean, Purdue University, Lafayette, Ind., Mem. Am.Soc.M.E.

coördinate the research work which has been carried on at Purdue for so many years, and to enable us to do it more satisfactorily, and to publish the results more widely. Another purpose in forming this organization in coöperation with the industries of the State is that primarily we are interested in Indiana, its products, its manufacturers, and its future, and it is going to be our first aim to collaborate with the men of Indiana to increase this productiveness. There is a certain advantage in a university laboratory. A university laboratory or engineering experiment station has no particular axe to grind, and this removes it from any suspicion of commercial interest. Sometimes we are required to investigate problems that perhaps could be better investigated by the private concerns but that establishment feels that its own efforts would be misinterpreted, and that the results from the engineering experiment station will receive more universal credence and support. The organization, and our methods of work, are very similar to those which Dean Richards has so well outlined. The time is too short to tell of the things that we are doing and expect to do. I will only mention one or two. One is the testing of road materials and the coöperation with the highway commissioners in the building of good roads. Another is the efficiency of the carburator. One of the most important however, of our investigations, is that of the farm tractor, in which we are coöperating with the agricultural school of the university. We expect to see a testing plant at the university which will bear somewhat the same relation to the farm-tractor proposition as the locomotive laboratory does to the problems of the railroad, and our only difficulty is to take care of the amount of work which it brings, and which comes to us without solicitation.

In conclusion, I wish to express my appreciation of the work of the research committee. I do, however, want to urge caution, not on the part of this committee, but on the part of perhaps some governing agencies in trying to shape research work. The research man is a genius. He is born, not made. He is peculiar and he must work in his own way and on his own initiative. He must not be interfered with, and he must be allowed to follow a thing in his own way.

J. R. BIBBINS,[1] as chairman of the Chicago Section of the Research Committee, offered the following resolution:

WHEREAS, it is a matter of generally accepted concern that any advanced policy of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS, in common with other complementary learned societies and associations, should incorporate prompt and extended recognition of scientific and industrial research as a specific means of advancing technology and proper industrial development of the nation; and,

WHEREAS, the Great War has fully demonstrated the principle of research, applied broadly as well as in detail, to be of inestimable benefit in advancing national welfare; and,

WHEREAS, the Committee on Aims and Organizations has specifically recommended that the AMERICAN SOCIETY OF MECHANICAL ENGINEERS take a more active interest in this field; therefore, be it

Resolved, That it be declared the sense of this research session of the A. S. M. E., that Engineering Council shall be encouraged to undertake active support of a plan and organization of scientific and industrial research to the end that the following objects may be accomplished with all reasonable dispatch:

1 To secure the passage in the present Congress of a special act furthering nation wide research in State units through congressional appropriations for this purpose under the general coördination of Engineering Council, or other national agency thoroughly representative of the engineering profession.

2 To encourage trade, industrial, and utility associations to interest themselves in the advance of the Arts and the constructive benefits to be derived from research work in their respective fields and to coöperate with them in their efforts in these directions.

3 To encourage the various research institutions or instrumentalities now or to be established by the Federal and State governments in their close coöperation in this general research policy.

4 To encourage and assist in the establishment of organized departments of engineering research at the various universities, adequately equipped with material and personnel and to bring such department as closely as possible in touch with the vital problems of industrial development confronting the Nation.

5 To institute organized publicity with the industries of the country and ascertain broadly by a thorough canvass their vital needs, with a view to directing the research work of the country and the coöperative development of the industries through the agency of the technical laboratories both public and private.

6 To organize and support a separate department of the societies activities, in close coöperation with similar departments of other technical societies, to act, through Engineering Council, or other representative national agency, as a permanent clearing house for all research work.

On presenting this resolution Mr. Bibbins stated that while there has been a considerable amount of discussion as to the propriety of state institutions undertaking work of this character he firmly believed in the necessity of each state developing itself as a unit. "They cannot do too much," he declared. "We should encourage by all possible means, every form of intelligent and efficient research. We do not disparage in the slightest degree purely scientific research and we recognize the absolute necessity of it. At the same time we also recognize the equal necessity of research in the more practical phases of the research work.

"The industries want men. They already have the money in abundance. Their executives are keen in search of improved materials, methods, and processes. If successful, the product instantly becomes better and cheaper. Many of the larger industries are alone spending millions for research of such a character as adapted to their essentially commercial undertakings. But what of the lesser industries? They have not the means to maintain expensive research laboratories, nor perhaps the vision to see the need of them, although it is these very industries that are most in need of encouragement. Where, then, may we find a solution of this modern pressing need?

"The answer seems to be in that agency that will produce men of vision, ability and perspective. These men are produced at the seats of learning, whose academic influence is admittedly nation-wide. They are usually supported by the State and indirectly through taxation by the industries. Yet for some reason, the impression of academic limitations still prevails in industry, although this is being gradually broken down by the splendid work of unselfish pioneers in technical learning who have given of themselves to obliterate the unfortunate impression.

"What can the A. S. M. E. do to secure recognition, establishment and support of a broad, nation-wide foundation for industrial research? The answer of the Chicago Research Committee, as far as present formulated, is found in the foregoing resolution, which is purposely suggestive and submitted to the Detroit Convention in the hope that concrete action will result."

Following Mr. Bibbins' presentation of the resolution offered by the Chicago Committee, there was a general discussion which centered around the question of governmental supervision of reasearch. The resolution was first discussed by Dean A. A. Potter, who stated that while he believed The American Society of Mechanical Engineers should encourage reasearch, and while it is unquestionably the purpose of the Society to urge governmental recognition, it would nevertheless be a mistake to approve a resolution asking Congress to appropriate a certain amount of money to support research in certain types of institutions. He believed that The American Society of Mechanical Engineers should express its approval of all kinds of scientific and industrial research, but should not approve any specific bill.

Doctor Mees, Director of the Eastman Kodak Research Laboratory, then took the floor and stated that he was in accord with Dean Potter's remarks and did not believe in urging Federal research. It was a question whether Federal research was desirable. The leaders of industry were against it, and the advice that he would give to the Society—he was not a member of it—was to pay for its own research.

Several members of the Society who favored financial assistance on the part of the Government next presented their views and urged that the Society endorse any measure which would obtain an appropriation from the National Government for the benefit of such institutions as might be selected.

C. H. Bierbaum also discussed the resolution. A bill of the kind proposed was proper enough from a theoretical point of view, but from a practical point of view he did not believe anything worse could be done than to have Congress pass a bill for Federal research, for there would then be a most inefficient distribution of

(*Continued on page* 718.)

[1] Engineer with Blon J. Arnold, Chicago, Ill., Mem.Am.Soc.M.E.

Suggested Formula for Rating Kerosene Engines

This and the Following Paper on Standards of Carburetor Performance, Together With the Discussion at the Gas Power Session of the Spring Meeting, Form a Timely Presentation of Subjects Dealing With Standardization of Internal-Combustion Engines

By D. L. ARNOLD,[1] CHICAGO, ILL.

At the present time there is no standard method of rating kerosene oil engines, and consequently engines of the same displacement are given different ratings by each manufacturer. A standard formula might therefore be of value and in this paper the writer discusses the various formulæ now in use and suggests that a piston displacement of 13,000 cu. in. per minute be taken as one brake horsepower. The subject of a standard nameplate is also discussed and a suggested form is given.

AMONG the various companies manufacturing kerosene engines there seems to be no uniform standard of rating in use, and as a result engines of the same bore, stroke and speed—or in other words, of the same piston displacement per minute—are given different ratings by almost as many manufacturers. In the past little attention has been paid to this minor detail, as it seems to have been considered, but the purchaser of engines and tractors has had much experience with this inconsistency. For instance, one buys an engine of 4 hp. that will actually develop 6.5 hp.; another buys one also rated 4 hp. but it will only develop 5 hp., and it will in all probability have a different piston displacement per minute. Apparently this means nothing as far as the customer is concerned, for in each case he receives more horsepower than he believed he was purchasing. A very great difficulty does arise, however, when these engines are judged by the amount of maximum work which they will perform in a given length of time, not on brake tests but on users' equipment, and the result is that the purchaser of the smaller engine is greatly dissatisfied, despite the fact that his engine will develop a 25 per cent overload.

The foregoing is only a sample case of the inconsistency which has resulted in many bills now being introduced, or about to be introduced, in state legislatures, specifying how an engine shall be rated. If these bills should all pass it might be that each state would require a different rating, and thus the manufacturers would be obliged to furnish a different nameplate in each state. It would therefore seem advisable for the manufacturers to get together and adopt a standard rating for kerosene engines. If standard rating is to be of service, it must give equal protection to the manufacturer and the customer, and any formula which is obtained must therefore be based upon practice covering a sufficient period of time. Before taking up the proposed formula, however, the writer wishes to review some of the formulæ that are in use today and which are listed on Table 1.

TABLE 1 FORMULÆ NOW IN USE FOR FOUR-STROKE-CYCLE ENGINES

D = diameter of piston, in. L = length of stroke, in.
n = number of cylinders N = number of revolutions per minute

No.	Authority	Formula
1	N.A.C.C.[1] or A.L.A.M.	$\frac{D^2n}{2.5}$ (at 1000 ft. per min.)
2	E. P. Roberts	$\frac{D^2LNn}{18{,}000}$
3	French Automobile Club	$0.45\ D^2n$ (at 985 ft. per min.)
4	Royal Automobile Club, British	$0.405\ D^2n$
5	Royal Automobile Club, Swedish	$\frac{D^2LNn}{15{,}240}$
6	Prof. H. L. Collanders	$0.565\ D(D-1)n$
7	T. Thornycrofts	$\frac{D^2L^{0.75}n}{2700}$
8	M. Faroux	$0.121\ D^{2.4}L^{0.4}$
9	M. Arnon	$0.1\ D^2n$
10	E. W. Roberts[2]	$\frac{D^2LNn}{X}$

[1] Vol. 1, p. 30, S.A.E. Standards Data Sheets.

[2] Gas Engine Handbook, p. 131. X is a factor varying with the fuel and cycle. For 4-cycle engines X equals 16,000 for natural gas and 14,000 for gasoline.

Formulæ Now Used for Four-Stroke-Cycle Engines

The A.L.A.M. formula[1] is based on the assumption that there is developed within the cylinder a mean effective pressure of 90 lb. per sq. in., that the engine operates with 75 per cent mechanical efficiency, and that the piston speed is 1000 ft. per min. With ungoverned engines this formula is perhaps as good as any, but for engines operating with governors it is obvious that if a piston speed of other than 1000 ft. per min. is maintained, it will be necessary to make a correction to cover this point, in which event the formula is unwieldy and inconvenient.

An empirical formula[2] which is considered as very conservative practice when compared with the various ratings now used by engine manufacturers is as follows: B.hp.$=0.00006042\ D^2LNn=V/13{,}000$. Before deriving this formula the writer compared the

[1] Derivation of A.L.A.M. Formula:

Let HP_b = brake horsepower
HP_i = indicated horsepower
HP_r = rated horsepower
A = area of piston, sq. in.
D = diameter of piston, in.
E = mechanical efficiency (assumed at 0.75)
L = length of stroke, in.
n = number of cylinders
P = mean effective pressure, lb. per sq. in. (assumed at 90 lb.)
V = piston displacement per minute, cu. in.
N = revolutions per minute
s = piston speed, ft. per min. (assumed at 1000)

$$HP_b = HP_i \times E = \frac{1}{4}\,\frac{PA_sNn}{33{,}000}\,E = \frac{90 \times 0.7854\ D^2 \times 1000 \times n \times 0.75}{4 \times 33{,}000 \times 12}$$

$$= \frac{D^2n}{2.489}, \text{ or for practical purposes, } \frac{D^2n}{2.5}$$

Also, since $s = \frac{2LN}{12}$

$$HP_b = \frac{90 \times 0.7854\ D^2 \times 2LN \times n \times 0.75}{4 \times 33{,}000 \times 12} = \frac{D^2LNn}{14{,}939} = 0.00006693\ D^2LNn$$

and substituting V for $0.7854\ D^2LNn$

$$HP_b = \frac{90 \times V \times 2 \times 0.75}{12 \times 33{,}000 \times 4} = \frac{V}{11{,}733}$$

[2] Derivation of Empirical Formula:

$$HP_r \text{ (recommended)} = \frac{0.7854\ D^2LNn}{13{,}000} = \frac{V}{13{,}000}$$

$$HP_r \text{ (transformed)} = \frac{D^2LNn}{16{,}550} = 0.00006042\ D^2LNn$$

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[1] Chief Engineer, Gas Power Engineering Dept., International Harvester Co., Chicago, Ill.

ratings of 115 engines manufactured by 61 companies and found them to vary from 8,256 to 19,985 cu. in. per b.hp. Forty-six engines were rated using 11,000 cu. in. or less as 1 b.hp.; 29 used 11,000 to 12,000 cu. in.; 12 used 12,000 to 13,000 cu. in.; 10 used 13,000 to 14,000 cu. in. and 18 used above 14,000 cu. in.

It will thus be seen that 87 engines or approximately 75 per cent were rated as using less than 13,000 cu. in. per b.hp. and while this value may be more conservative than some manufacturers might wish to use, it gives a standard basis of comparison and allows the engine to develop a fair percentage of overload above its rating, since any engine should be able to develop as a maximum 1 b.hp. per 11,000 cu. in piston displacement per min. when the engine is in good condition.

At this time it seems desirable to compare this new formula with those already in use, and for that reason Table 2 has been

TABLE 2 COMPARISON OF ENGINE-RATING FORMULAE

Formula No.	Authority		Expressed in piston displacement per minute	Expressed in terms of Roberts formula
1	N.C.C.C. or A.L.A.M.		$\frac{V}{11{,}733}$	$\frac{D^2LNn}{14{,}939}$
2	E. P. Roberts		$\frac{V}{14{,}137}$	$\frac{D^2LNn}{18{,}000}$
3	French Automobile		$\frac{V}{13{,}180}$	$\frac{D^2LNn}{16{,}781}$
5	Royal Automobile Club, Swedish		$\frac{V}{11{,}969}$	$\frac{D^2LNn}{15{,}240}$
		16000	$\frac{V}{12{,}566}$	$\frac{D^2LNn}{15{,}999}$
10	E. W. Roberts	14000	$\frac{V}{10{,}995}$	$\frac{D^2LNn}{13{,}998}$
		11500	$\frac{V}{9{,}032}$	$\frac{D^2LNn}{11{,}499}$
11	Rated Horsepower Recommendation		$\frac{V}{13{,}000}$	$\frac{D^2LNn}{16{,}550}$

compiled. It should be noted, however, that the table does not show the maximum horsepower that can be expected from an engine but has reference only to the rated brake horsepower which should be reasonably expected. If one engine can develop a higher maximum than another, or, in other words, can make good on a lower piston displacement per minute than its competitor, the credit is certainly due to the manufacturer who can consistently produce these conditions. However, practically all engines of correct design will develop a maximum horsepower according to the formula heretofore given, namely 1 b.hp. per 11,000 cu. in. piston displacement per minute.

With reference to the rating of four-stroke-cycle engines, it would seem best for all concerned that this rating should be made the nearest whole horsepower to that determined by the standard formula, it being a very easy matter to change the rated speed of the engine in order to accomplish the exact rating. In any event, however, the rated horsepower would not, if the foregoing condition is adhered to, vary more than plus or minus 0.5 hp.

Tractor-Engine Nameplates

Having established a standard rating for this class of engine, there should also be a standardized nameplate; to state the horsepower alone with no reference to speed is insufficient and misleading. This nameplate should be clear and concise, leaving no cause for doubt as to what is meant.

In considering the internal-combustion-engine rating we must also consider the tractor rating as the internal-combustion engine forms its power unit and the tractor rating is therefore dependent upon the engine rating. The owner of a tractor is not only interested in the amount of power that can be delivered by the engine but also in the amount that can be delivered to the drawbar at the different speeds. Here again, however, manufacturers have been inconsistent in the ratings which they have made. The majority of manufacturers have followed the rule that drawbar horsepower should be considered as 50 per cent of the rating of the power unit and in actual practice covering many years of experience this seems to be a very conservative figure to use. It is true that the tractor will often develop greater drawbar horsepower, but when taking into consideration the wide range of conditions through which the tractor must work, such as changes of soil and class of work, a 50 per cent rating for the drawbar

16 Brake HP at 500 RPM
8 Drawbar HP at 500 RPM of the engine
Drawbar pull:
—— lb., reverse speed at —— miles per hour
—— lb., first speed at —— miles per hour
—— lb., second speed at —— miles per hour
—— lb., third speed at —— miles per hour
Drawbar pull and HP are on the average good footing.

pull seems on the whole to be the best value to use; therefore, on the tractor engines it would seem that the best nameplate would be one like that given above.

Formulæ Best Adapted to Rating Engines and Tractors

The following formulæ are those which it would seem are best adapted to the rating of internal-combustion engines and tractors:

$$\text{Rated engine horsepower} = \frac{0.7854\, D^2LNn}{13{,}000} \quad \ldots\ldots [1]$$

$$\text{Drawbar horsepower} = \frac{HP_e}{2} \quad \ldots\ldots [2]$$

$$\text{Drawbar pull,}^1 \text{ lb.} = \frac{375 \times HP_d}{S} \quad \ldots\ldots [3]$$

$$\text{Motor torque,}^2 \text{ in-lb.} = \frac{63{,}025.21 \times HP_b}{N} \quad \ldots\ldots [4]$$

Practical work in experimental testing laboratories and on regular test floors has proved that four-stroke-cycle engines operating on kerosene will develop for periods of two hours or more 1 b.hp. per 11,000 cu. in. piston displacement per min. and a few engines have for short periods of time developed 1 b.hp. for every 9800 cu. in. piston displacement per min. Therefore, making allowances for general wear, mishandling and improper adjustment, the four formulæ given in the preceding paragraph will be seen to be conservative and well adapted for the rating of this type of engine.

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[1] Derivation of Drawbar Pull Formula:
Let F_d = drawbar pull, lb.
HP_d = drawbar horsepower
S = speed in miles per hour

$$\text{Then } F_d = \frac{HP_d \times 33{,}000 \times 60}{5280 \times S} = \frac{375\, HP_d}{S}$$

[2] Derivation of Motor Torque Formula
Let HP_b = brake horsepower
l = length of brake arm, in.
W = lb. pull at end of arm
N = revolutions per minute
T = motor torque, in-lb.

$$\text{Then } HP_b = \frac{2\pi\, lnW}{33{,}000}$$

$$T = \frac{HP_b \times 33{,}000 \times 12}{2\pi N} = \frac{63{,}025.21 \times HP_b}{N}$$

Standards of Carburetor Performance

By O. C. BERRY,[1] LAFAYETTE, IND.

The type of test which a carburetor is most frequently given to establish its merit or lack of merit is carried out in the following manner: An engine in good mechanical condition is tested, using a carburetor which bears a high reputation. These tests are then repeated, using the new carburetor, and its merits are thus reported in terms of the comparative performances of the engine. The results of these tests are valuable and convincing, and while they will always be the final criterion of carburetor performance, they fall a little short of the ideal in that they fail to show the reasons for the differences. Several writers have recently pointed this out and suggested that the performance of a carburetor should also be expressed in terms of its ability to perform those functions which are essential to proper carburation. In order to do this it will be necessary to determine these essentials. This is a difficult task, but its accomplishment should prove of great benefit. In this paper a list of the essential factors, as now understood, has accordingly been made and some experimental data are also presented which it is hoped will help to establish certain of the standards of performance.

SATISFACTORY carburation of a liquid fuel depends jointly upon the carburetor, the intake manifold, and the temperature of the combustion-chamber walls. These parts may therefore be considered the carburating apparatus and the headings under which are grouped the tests to determine the degree of excellence with which each of these parts performs its respective functions may all be listed together. These headings, expressed in the general order of their importance, are as follows:

a The range of flow-rate capacities, or, in other words, the maximum and minimum number of cubic feet of air per minute that can be handled

b The richness of the mixture as affected by: the rate of flow of the air through the carburetor; sudden changes in the rate of flow; the amount the throttle is open

c The pressure drop through the carburetor at different rates of flow

d The thoroughness and uniformity with which the fuel and air are mixed

e The uniformity of the richness of the mixture furnished to the different cylinders

f The temperature and dryness of the mixture entering the cylinders

g The temperature of the combustion-chamber walls, particularly the piston head.

The relative importance of these items is largely a matter of opinion and will be different under different conditions. For example, the capacity for handling large amounts of air is much more important in passenger cars than in trucks and tractors, while in tractors using kerosene the temperature of the mixture and combustion-chamber walls becomes comparatively much more important than it is in passenger cars burning gasoline.

Items To Be Investigated

Range of Flow-Rate Capacities. In passenger-car engines great importance is attached to flexibility, and the buying public would not consider a car that was notably defective in this respect. The power developed by an engine varies almost directly with the weight of air used per minute, and the carburetor must therefore be able to supply this air, properly mixed with fuel, through a wide range of flow rates.

The passenger car is expected to idle down to one or two miles per hour on high gear and at the same time have a maximum speed capacity well above 50 miles per hour. Few carburetors are capable of furnishing a proper mixture over so wide a range, although most carburetors are sold under claims of wonderful flexibility.

A carburetor is truly suited to an engine only when its flow-rate capacities correspond to the requirements of the engine, and this condition will be attained with the greatest certainty when the requirements of the engine and the capacities of the carburetor are both given in cubic feet of air per minute. It is therefore suggested that the flow-rate capacities of all carburetors should be stated definitely in cubic feet per minute, and that this information should always accompany the statement of the size of the carburetor flange.

With the carburetor adjusted so that the engine carries its full torque with open throttle, the air required per brake horsepower per minute will remain nearly constant irrespective of the amount of gasoline used or the speed of the engine. For the usual passenger-car type of engine with compression ratio of about 4 to 1 this constant is about 2.1 cu. ft. per min. at full power, and seldom exceeds 2.3 cu. ft. per min. The air used when idling at any speed is almost exactly one-quarter of that used under full load at the same speed. With these data, which are based upon the performance of the engines tested at Purdue, it is easy to compute the air requirements for any engine of the same type, for any torque and any speed.

Richness of the Mixture. The thermal efficiency of an engine at any speed and load is affected more by the richness of the explosive mixture than by any other factor. It is therefore highly important that the carburetor deliver the mixture to the engine in the proper proportions, at all speeds and loads. The richness of mixture giving the best power and the one giving the best efficiency must each be experimentally determined for various speeds and loads, so as to learn what effect a change in either will have on the mixture requirements of the engine. The temperature and the dryness of the mixture must also be varied to determine whether or not they affect the power or efficiency of the engine.

In the Purdue tests the richness of the mixture is expressed in pounds of gasoline per pound of dry air. With a dry mixture at half load and 1000 r.p.m., regular firing may be obtained with mixtures between 0.0575 and 0.12. The best efficiency under the same conditions accompanies a mixture of about 0.067, and the best power, 0.08. The method used in obtaining these results and a few of the characteristic curves will be presented at the end of this paper.

Pressure Drop Through the Carburetor. It is always necessary to have the gasoline in the float chamber of the carburetor at a lower level than the delivery orifice in order to prevent overflowing when the engine is not running, and the suction in the carburetor must be great enough to overcome this safety head before any gasoline will be delivered. The best attainable condition, therefore, will be to have just enough vacuum in the carburetor to cause a satisfactory flow of fuel and air, and no more. Because of the influence of volumetric efficiency on engine capacity the importance of a small carburetor vacuum is very great.

Thoroughness of the Mixing. The thoroughness and uniformity with which the fuel is mixed with the air is important. One of the greatest helps in reducing the fuel to a gas is to atomize it thoroughly and mix it with the air. This gives the fuel a large amount of exposed surface and helps to bring all parts of the mixture up to the same degree of saturation.

The mixture in all parts of each individual cylinder must be uniform and the fuel reduced to a gas at the end of the compression stroke or else the combustion will not be complete, thus lowering the power and efficiency of the engine and causing uneven running. Therefore, if the engine runs with a regular and even exhaust, the thoroughness of the mixing is probably good

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[1] Professor of Mechanical Engineering, Purdue University.

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along with all of the other factors influencing engine performance. The best direct test of the quality of the mixing is to have the carburetor discharge into a section containing glass placed between the carburetor and manifold. The best dry mixtures appear as colorless and dry as pure air, while wet mixtures resemble a fog, and in most cases streams of liquid fuel are seen following a spiral path along the walls of the manifold.

Uniformity of Mixture to All Cylinders. The richness of the mixture entering the various cylinders often differs widely, especially when very wet mixtures are used. Some manifold designs also aggravate this condition. The results attained by any given manifold may be tested by removing the exhaust manifold and observing in comparative darkness the flames from the exhaust openings. By adjusting the carburetor for continuously leaner mixtures the impoverished cylinders will be caused to miss, and then by gradually enriching the mixture the yellowish flame will indicate the cylinder with the rich mixture.

Temperature and Dryness of the Mixture. With the rapidly increasing difficulty in vaporizing the commercial liquid fuels, the temperature of the mixture becomes a more and more important consideration. Before the fuel can be burned it must be vaporized, and this requires both heat and time. The mixture should be dry and thoroughly mixed at the end of the compression stroke in order to get good combustion, and the gas temperature should be as low as possible at the end of the suction stroke, in order to keep up the volumetric efficiency. It is therefore desirable to make the fullest possible use of the heat in the combustion-chamber walls, piston head and compression, and to introduce the mixture into the cylinder as wet as possible and still be sure of having it dry before it is burned.

It is possible to compute approximately the change in power that will accompany a definite change in the temperature of the mixture furnished to the engine. The computation is based upon the fact that the density of a gas varies inversely as its absolute

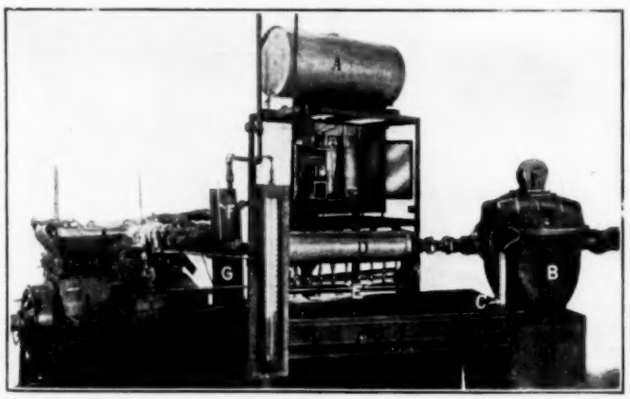


FIG. 1 WILLYS-KNIGHT ENGINE AND EQUIPMENT FOR TESTING ITS CARBURETOR

A, gasoline tank; *B*, air meter; *C*, manometer; *D*, heater; *E*, gas jets; *F*, thermometer; *G*, water tank

temperature. Since the power generated in the cylinder varies almost in direct proportion to the weight per minute of the mixture used, it will vary almost in the inverse ratio of the absolute temperatures of the mixtures. As an illustration, suppose the engine will develop 12.5 hp. when the mixture has a temperature of 250 deg. fahr. What will it develop when the temperature is 60 deg. fahr.? The power times the inverse ratio of the mixture temperatures is as follows:

$$12.5 \times \frac{460 + 250}{460 + 60} = 17.06$$

This indicates that 17.06 hp. is to be expected with the 60 deg. fahr. mixture. As a matter of fact, the temperature in the cylinders at the end of the suction stroke rather than the intake manifold temperature determines the density of the charge, but this temperature cannot be measured. Again, the indicated rather than the brake horsepower is the one that varies with the density of the charge, while the brake horsepower is the one that is usually measured. These are the main reasons why the results obtained are only approximately correct. The figures given are from two Purdue tests run at the same speed with the same throttle orifice, and the power was increased from 12.5 to 16.0 instead of 17.06 b.hp.

The task of determining the best method of introducing into the mixture the heat for vaporizing the fuel is both important and difficult and will require considerable careful experimentation. The Purdue tests with the "hot spot" warrant the conclusion that it is superior to any method of preheating the air, in that it dries the mixture sufficiently at lower temperatures and, therefore, does not decrease the power of the engine so much. These tests also indicate that the design of the hot spot is still in need of experimental development.

Temperature of the Combustion Chamber. When the mixture is dry as it enters the cylinders, or the fuel so well atomized that it remains suspended in the air and is entirely vaporized during the compression stroke, the heat absorbed from the combustion-chamber walls does not improve the carburation, but decreases

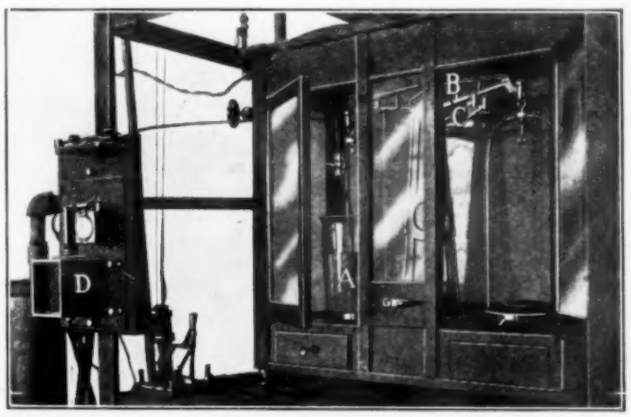


FIG. 2 SCALES FOR WEIGHING GASOLINE, AND ELECTRICAL EQUIPMENT FOR STARTING AND STOPPING TESTS

A, gasoline beaker; *B*, balances; *C*, mercury cups; D, magnet

the power capacity of the engine without improving either its efficiency or the way it runs. These conditions, however, are rare. A considerable portion of the fuel usually enters the cylinders as a liquid, which collects on the piston head. Under these conditions the temperature of the combustion-chamber walls, especially the piston head, becomes very important. The jacket-water temperature should therefore be kept high when the piston head is depended upon to flash any considerable amount of liquid fuel into a gas. This conclusion is borne out by the engine tests. With the air entering the carburetor at 70 deg. fahr. and the jacket water maintained at 110 deg., the engine would not fire regularly with any richness of mixture. When the jacket-water temperature was raised to 200 deg. fahr. the engine would fire some of the richer mixtures regularly, and by raising the air temperature to 80 deg. fahr. the engine developed full power and efficiency and would fire a wide range of mixtures.

THE PURDUE TESTS

The tests at Purdue University were carried out on a Haynes Light Six and a Willys-Knight four-cylinder engine, mounted on a Diehl electric dynamometer. Fig. 1 shows the Knight engine mounted ready for a test. Fig. 2 gives a more detailed view of the scales and the electrical apparatus for starting and stopping the tests. The supply of gasoline is piped from tank *A*, Fig. 1, into a 2-qt. glass vessel placed in one of the scale pans. This is shown at *A*, Fig. 2. In order to give the balances freedom of motion, the gasoline was siphoned from this vessel to the carburetor. The balances *B*, Fig. 2, were capable of weighing the

gasoline to the one-hundreth part of an ounce, and were equipped with wires dipping into mercury cups *C*, Fig. 2, which completed an electric circuit just when a balance was reached. The hand on the dial of the air meter was equipped with an electrically operated clutch and brake, the stop watch was operated by a

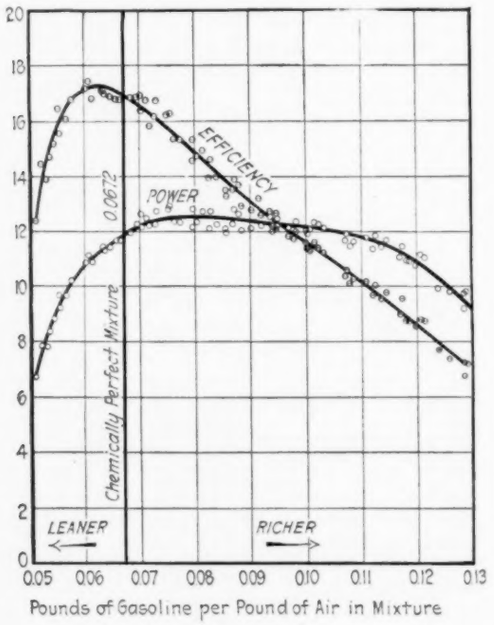


FIG. 3 POWER AND EFFICIENCY CURVES OF WILLYS-KNIGHT ENGINE
Throttle set for half-load. Speed, 1000 r.p.m. Cooling-water temperature, 200 deg. fahr.

strong magnet *D*, Fig. 2, and the revolution counter on the end of the dynamometer shaft was electrically operated. By these means, when the scales came to a balance they would start the stop watch, the revolution counter and the recording hand on the air meter and ring a gong. Weights corresponding to the gasoline to be used were then removed from the scale pan, and when the scales again came to a balance the recording apparatus was electrically stopped, making it possible to time all of the readings together and make the record at leisure from instruments that were standing still.

The air was metered through an Emco No. 4 gas meter *B*, Fig. 1, reading to cubic feet, so that tenths of a cubic foot could be estimated. The drop in pressure through the meter was indicated by the water manometer *C*, Fig. 1. The barometer and the wet and dry-bulb readings on a hygrometer were taken periodically, so as to be able to determine the pounds of dry air used in each instance.

The meter was connected by rubber tubing to a heater *D*, Fig. 1, made up of 4 ft. of 3-in. wrought-iron pipe surrounded by an asbestos cylinder with a space between large enough to allow the pipe to be heated by the flames from the gas burners *E*. The exit air temperature was indicated by the thermometer *F* whose bulb was exposed directly to the air inside of the pipe. The temperature of the air could be regulated within close limits by careful adjustment of the gas flames. In some instances a section containing glass was inserted between the carburetor and engine, which offered ample opportunity to observe the character and behavior of the mixture inside.

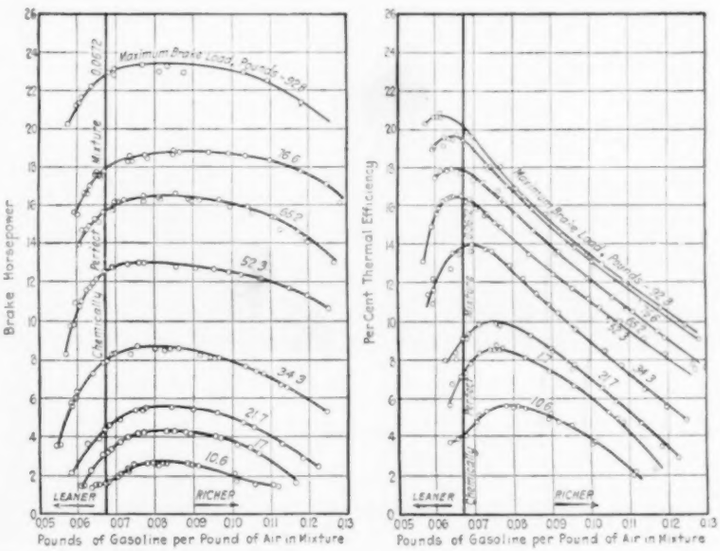
The speed of the engines was read on a tachometer as well as being computed from the stop-watch and revolution-counter readings. The torque developed by the dynamometer was weighed by means of a sensitive set of Fairbanks scales. This is the same as the brake load on the engine, thus making it possible to compute the power developed by the engine to a satisfactory degree of accuracy.

The object of the first series of tests was to determine the effect of changing the richness of the mixture on the performance of an engine. It was planned to determine the mixture that would give the best power, the one for the best efficiency and the range of mixtures that could be fired regularly.

ACCURACY OF RESULTS

The vertical line in Fig. 3 (at 0.0672) represents the chemically perfect mixture, or the one in which there is just enough oxygen in the air to burn the fuel and no excess of either fuel or air exists. The curves show that the engine will run with a mixture as lean as 0.05 lb. of gasoline per lb. of air, but will not pull well with so lean a mixture. The test log shows that it misses frequently at this power, but that the performance becomes better as the mixture is made richer, until at 0.055 it fires every cylinder regularly. The best efficiency is obtained at 0.063, when the engine is developing 91 per cent of its maximum power capacity with this orifice at 1000 r.p.m. The best power accompanies a mixture of about 0.08, at which point the thermal efficiency has dropped from 17.25 to 14.8 per cent. The richest mixture that can be fired regularly is about 0.1275, but the engine will run with mixtures as rich as 0.135. Nearly full load can be carried with a mixture as lean as 0.065, or as rich as 0.115. In other words, a carburetor can be adjusted with as lean a mixture as can be used to carry full load and the amount of gasoline can be nearly doubled without greatly affecting the power developed or the smoothness of running of the engine.

In applying the information obtained from these tests to other conditions it must be remembered that these results are for half-load at 1000 r.p.m. when a warm mixture was used that was dry as it left the intake manifold. Before applying the conclusions to other conditions, one must learn the effect of the load carried, the speed and the temperature and dryness of the mixture upon the mixture requirements, power and efficiency of an engine.



FIGS. 4 AND 5 POWER AND EFFICIENCY CURVES OF WILLYS-KNIGHT ENGINE
Throttle set for various loads. Speed, 1000 r.p.m. Temperature, air to carburetor, 150 deg. fahr. Cooling water temperature, 120 deg. fahr.

EFFECT OF LOAD UPON MIXTURE REQUIREMENTS

Figs. 4 and 5 show the power and efficiency curves taken from the Willys-Knight engine running at 1000 r.p.m., but with different throttle orifices. During these tests the temperature of the air entering the carburetor was kept at about 150 deg. fahr., and the cooling water at about 120 deg. fahr. This was true of all of the curves excepting the one for 92.8 lb., in which case the mixture was heated up to 125 deg. fahr. in a "hot spot" and the

cooling-water temperature was 160 deg. fahr. Fig. 4 shows that the mixture giving the best power at a fixed throttle setting does not vary with the brake load carried, but remains constant at about 0.08. At light loads the engine will not operate well with as wide a range of mixtures as it can use when carrying more nearly its full capacity. Fig. 5 shows that with light-load throttle settings the mixtures for best power and best efficiency tend to coincide, but as the brake load is increased the mixture for best efficiency becomes continuously leaner, until at full load it is 0.062. In the case of the higher brake loads the engine will hit regularly and run smoothly with the lean mixtures which give the high efficiencies, but the power developed is reduced considerably below the highest attainable at that throttle setting. The most satisfactory mixture for general use at or near full load will therefore be approximately 0.067, giving almost full power and nearly the best efficiency. For higher pulling conditions the mixture had better be caused to approach 0.08, the one for best pulling.

Effect of Speed Upon Mixture Requirements

In Fig. 6 is shown a set of curves taken from tests on the Haynes Light Six engine. The curves show that the mixture giving the best power is not noticeably affected by changes in speed, but that at high speeds the engine cannot hold up its power with quite as much excess fuel as at lower speeds. The data sheets show that the mixture for the highest efficiency also remains unchanged.

Effects of Changing Air Temperatures

Figs. 7 and 8 show a series of curves taken from the Willys-Knight engine with air furnished to the carburetor at temperatures varying from 80 to 275 deg. fahr. They show that 80 deg. fahr. air gives the most power and the best efficiency, but that at so low a temperature the engine is unable to use the lean mixtures. Each increase in the air temperature decreases the power of the engine. Up to 150 deg. fahr. the ability of the engine to use the lean mixtures also increases. From 150 to 300 deg. fahr. air temperatures the engine develops its best ability to hit regularly and run smoothly with the lean mixtures, firing every cylinder with a mixture as lean as 0.055. Fig. 8 gives the efficiency curves. The best efficiencies at 80 and 125 deg. fahr. are nearly exactly the same, 18.75 per cent, but at 80 deg. fahr. it accompanies a mixture slightly richer than for 125 deg. fahr. Each increase in temperature between 125 and 275 deg. fahr. decreases the efficiency slightly. At 150 deg. fahr. the mixture for the highest efficiency reaches its leanest point, 0.063, and remains the same up to 275 deg. fahr. The effects of increasing the temperature of the air entering the carburetor above 80 deg. fahr. are therefore to decrease the power capacity of the engine considerably and its efficiency slightly, but to make it fire regularly when using leaner mixtures.

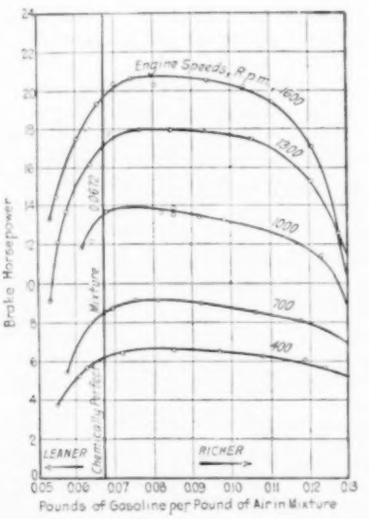
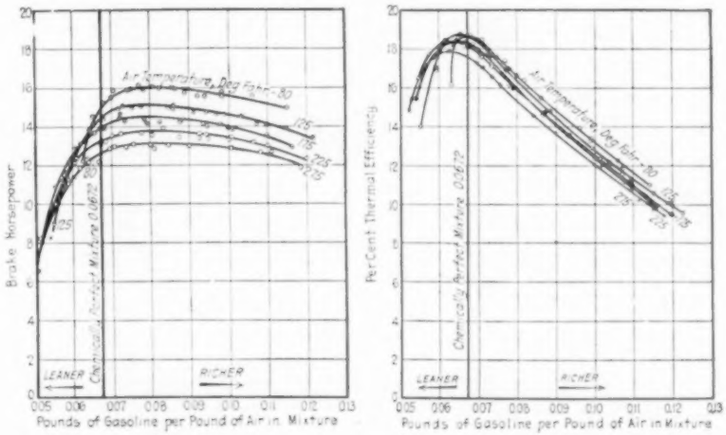


Fig. 6 Speed Curves of Haynes Light Six Engine
Throttle set for half load. Temperature, air to carburetor, 100 deg. fahr. Cooling-water temperature, 130 deg. fahr.



Figs. 7 and 8 Heated-Air Test Curves, Willys-Knight Engine
Throttle set for half load. Speed, 1000 r.p.m. Cooling-water temperature, 200 deg. fahr.

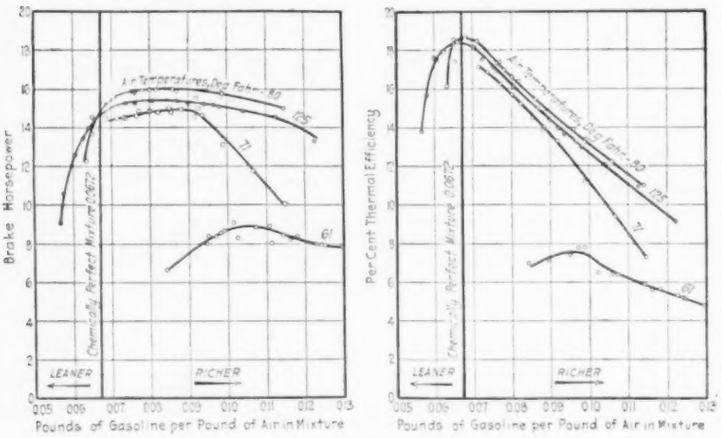
Figs. 9 and 10 show the curves for the same series of tests, but with colder air temperatures. Fig. 9 shows that with an air temperature of 61 deg. fahr. the engine could use only the comparatively rich mixtures and its power capacity was greatly reduced. When the air temperature was increased to 71 deg. fahr. the power was brought nearly up to maximum, but still the engine could not fire the leaner mixtures with regularity. Fig. 10 shows that the efficiency for the 61 deg. fahr. air is very poor, while the 71 deg. fahr. air was much better but the engine stopped before it reached a lean enough mixture to give the best results. It may therefore be seen that 80 deg. fahr. is about the lowest temperature at which the air may be drawn into a carburetor when using Red Crown power gasoline, to get good carburation in an engine having a 200 deg. fahr. cooling-water temperature. If the cooling-water temperature is lowered the temperature of the air will have to be raised correspondingly, while raising the quality of the gasoline will improve the performance with cold air, cool water or both.

The Hot-Spot Tests

Figs. 11 and 12 show curves taken from the Willys-Knight engine using a "hot spot" between the carburetor and the intake manifold. This hot spot was designed to flash the liquid fuel into a gas while heating the air as little as possible. The curves show that by using the hot spot the engine is able to fire the lean mixtures without in turn lowering either its power or its efficiency. The explanation is that the factor controlling the power of the engine is the weight of air that can pass through the throttle orifice in a given time. The air always being cold when it passes this point, the power is not affected by the heat. This is always true for a throttled condition, but as the throttle is opened and the manifold or valves become the limiting factors in the production of power, the advantage of the hot spot decreases, but it does not disappear. It is therefore clear that the method of introducing heat into the mixture by means of a hot-spot is superior in every way to the hot-air method, and particularly so when the engine is throttled down.

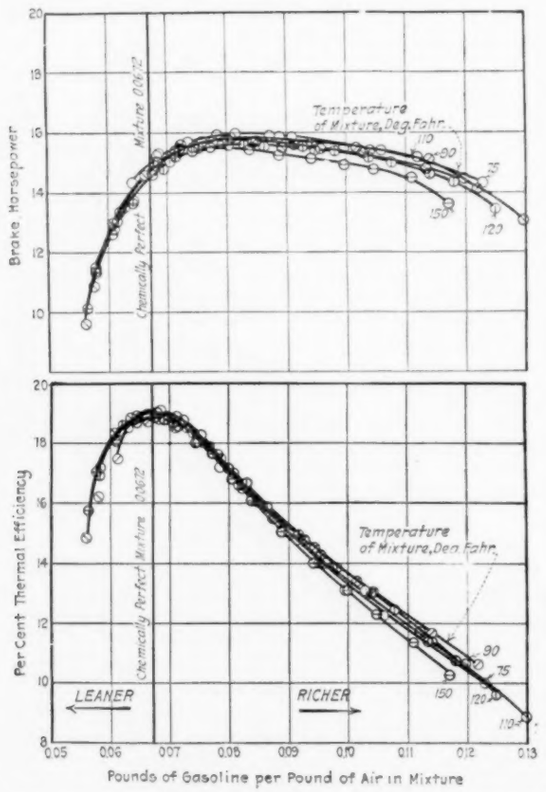
Conclusions

It may be well to again point out the importance of judging the merit of a carburating system in terms of the degree of thoroughness with which the system performs those functions which are necessary to proper carburation. It is hoped that a discussion of the topic will result in establishing specifications for these tests, and that many may join in the task of carrying out the experiments that will determine the standards of performance in each case. Tests are needed showing the richness of mixture that will give the best power and the one for best efficiency when using liquid fuels other than gasoline. It would also be interesting to extend the gasoline tests to include wider ranges of speed and higher compression.



Figs. 9 and 10 Cold-Air Test Curves, Willys-Knight Engine

Throttle set for half load. Speed, 1000 r.p.m. Cooling-water temperature, 200 deg. fahr.



Figs. 11 and 12 "Hot Spot" Test Curves, Willys-Knight Engine

Throttle set for half load. Speed, 1000 r.p.m. Cooling-water temperature, 200 deg. fahr.

The problem of determining the best method of introducing into the mixture the heat necessary to vaporize the fuel is one of great importance, especially in connection with the heavier fuels. As a part of this problem it will be interesting to determine the actual temperatures found in the metal of the piston head and cylinder walls of automobile, truck and tractor engines, and how these temperatures affect the carburation.

The fullest discussion of these problems and the methods employed at Purdue in attacking them is earnestly solicited, and any suggestions in connection with carrying out this line of investigations will be received most gratefully by those in charge of the Purdue Engineering Experimental Station.

Acknowledgments

The experimental work presented in the foregoing paragraphs was carried out in the laboratories of Purdue University under the direction of the Purdue Engineering Experiment Station, and has received throughout the personal attention and encouragement of Prof. G. A. Young, Head of the School of Mechanical Engineering. Most of the tests were carried out and the computations made by Mr. C. S. Kegerreis, Research Assistant. It is hoped that the Experiment Station will have a bulletin on carburation ready for distribution by early winter, and it is planned to present in this bulletin a detailed report of the work which has been summarized in this paper, and also to include such other data as are then available for publication. When available, copies of this bulletin may be obtained by addressing C. H. Benjamin, Director of the Engineering Experiment Station, Purdue University, Lafayette, Indiana.

Although there is scant information on the service and cost of treated roof timbers in cotton mills, paper mills, and other buildings where high humidity causes rapid decay, a number of preservative treatments which it will undoubtedly pay to use may be suggested.

The steeping process consists merely in soaking the timber in a water solution of a preservative such as zinc chloride, sodium fluoride, or mercuric chloride. The wood must be thoroughly seasoned. It is left in the solution 1 day for each inch in thickness and 1 additional day. After treatment, the timber should be air dried before using. Specific directions for the use of this process (and they are especially necessary for handling mercuric chloride) may be secured from the Forest Products Laboratory, Madison, Wis. Zinc chloride attacks lead paints, but is very desirable otherwise. Mercuric chloride is very effective, but is poisonous and has a decided corrosive action on steel, so that steel tanks cannot be used with it. Sodium fluoride does not attack paint, is not corrosive, and in most other respects is very desirable.

Timbers may be coated with coal-tar creosote by a brush treatment, by dipping in hot oil for 5 to 15 minutes, or the hot- and cold-bath method. This last method consists in submerging the lumber in hot oil for several hours and then either allowing the oil to cool down slowly with the wood in it or plunging the wood into cool oil and leaving it for several hours.

Although pressure treatments are the most expensive, they are the most effective because they result in the greatest absorption and penetration of preservative. Roof planking should receive 8 to 12 lb. of creosote per cubic foot, or 0.5 lb. of the salt if zinc chloride is used. Such treatment should add at least 20 years to the life of roof plank.

Whenever it becomes necessary to cut into treated timber, the untreated wood exposed by cutting should be given two brush coats of creosote or some other preservative.—Technical Notes, No. A-3, Forest Products Laboratory, U. S. Forest Service, Madison, Wis.

DISCUSSION AT GAS POWER SESSION OF SPRING MEETING

THREE papers were read and discussed at the Gas Power session of the Spring Meeting, held on the morning of Wednesday, June 18, under the auspices of the Sub-Committee on Gas Power, Prof. W. T. Magruder presiding. The titles of the papers were: Crude Oil Motors versus Steam Engines in Marine Practice, by J. W. Morton; A Suggested Formula for Rating Kerosene Engines, by D. L. Arnold; and Standards of Carburetor Performance, by O. C. Berry. Mr. Morton's paper appeared in the July issue of MECHANICAL ENGINEERING (p. 609) and consisted of a discussion of the various factors to be considered in choosing the form of motive power for war vessels and cargo ships, together with a presentation of the advantages as compared to steam engines of high- and low-powered oil motors of both the constant-pressure and constant-volume type. The relative values of four-stroke cycle, two-stroke cycle, double-acting, and horizontal oil motors were also compared and some details of their construction such as lubrication systems, piston cooling and scavenging pumps were analyzed. The papers by Messrs. Arnold and Berry will be found elsewhere in this issue.

DISCUSSION OF MR. MORTON'S PAPER ON CRUDE-OIL MOTORS VS. STEAM ENGINES IN MARINE PRACTICE

LOUIS ILLMER[1] (written). In the paper under discussion, Mr. Morton apparently favors the four-stroke oil engine and appears to give insufficient credit to the recent advances made in heavy-duty two-stroke engine design as applied to the merchant-marine service.

Undue complication of mechanism is probably chiefly responsible for the slowness on part of the American shipbuilder in adopting the oil engine for the propulsion of large cargo ships, since each additional vital moving part adds to the first cost, the liability to accident and the overhauling required for maintenance of operating efficiency.

Other things being equal, the oil engine with the least number of vital working parts will most adequately meet the demand for reliable low-cost power, particularly so under American conditions of high labor and relatively low fuel costs.

It is conceded that a perfected oil engine of the two-stroke type admits of the simplest possible construction for marine propulsion. The four-stroke marine engine suffers from inherent difficulty in reversing the mechanically operated inlet and exhaust valves as driven from the half-speed cam-shaft drive. Furthermore, the long-stroke slow-speed engine of the four-stroke type does not compare favorably in weight, floor space or in first cost with the cargo-ship type of two-stroke engine.

With but a single power impulse per cylinder for every two revolutions, the heavy power parts of a four-stroke engine do not work to advantage during the idle inlet- and exhaust-stroke periods. Hence the two-stroke engine is enabled to show a decided weight reduction and consequent lowering in first cost. For example, a six-cylinder slow-speed two-stroke engine suitable for cargo-ship propulsion can readily be made to deliver approximately $1\frac{3}{4}$ times as much shaft power for the same weight and floor space as will a four-stroke oil engine of the same speed and bore. This advantage is of decided importance when large merchant ships are to be engined, since the usefulness of such a prime mover is determined in a large measure by the ultimate power capacity to which a compact six- or eight-cylinder unit can be built.

Another advantage of the two-stroke engine is that it requires no mechanically operated inlet and exhaust valves. The cylinders of such oil engines are best charged from the under side of the power piston, through inlet poorts overrun by the piston. If desired, the scavenging air supply may be supplemented by additional low-pressure pumps but this is not essential when liberally proportioned injection-air compressors are provided.

With this mode of charging a two-stroke cylinder, the timing events of the inlet and exhaust ports must be correctly proportioned and the shape of the piston deflector lug must be properly designed to produce effective scavenging of the power cylinder, otherwise the incoming fresh-air charge will blow out of the exhaust ports without displacing the burnt products of combustion. Deficiency in oxygen for combustion of the fuel oil has been responsible for the failure of a number of two-stroke engine designs.

The described mode of charging two-stroke power cylinders reduces the valve gear parts to a minimum and requires only one air starting valve and one fuel valve opening into each cylinder head. Since these valves run in unison with the piston movements, they may be eccentric-driven and reversed by a Stephenson link in the manner of a steam-engine gear. The elimination of the half-speed cam-shaft drive is a feature of the two-stroke engine that makes for a simple and compact reversing valve gear.

While the thermal efficiency of a well-designed two-stroke engine is not quite as high as that of a four-stroke engine, the difference is not large. Most of the loss of economy is chargeable to the increased pump work required to charge the power cylinder, but the relatively small gain of about 10 per cent in brake efficiency in favor of the four-stroke engine is not in itself sufficient to offset the other advantages which a perfected two-stroke engine affords.

A good two-stroke engine is somewhat more difficult to design than a four-stroke engine, partly because of the greater heat flow through the cylinder walls. For equal bore dimensions, the rate of heat flow in a two-stroke engine is approximately 1.6 times that in a four-stroke engine running at the same speed.

The limiting rotative speed at which an oil or gas engine may be safely run is largely determined by the temperature assumed by the cylinder-bore wall, and if this is not kept within prescribed limits, troubles from piston lubrication and cracking of cylinder parts will result.

The temperature head required to drive heat at a given rate of flow through the cylinder wall increases with the wall thickness. For equal shaft power the bore dimensions of a four-stroke oil engine are about 4/3 those required for a two-stroke engine. Allowing for the thicker four-stroke cylinder wall and assuming equal rotative speeds, the rate of heat flow in the case of the two-stroke engine should not exceed 5/4 that obtained in a four-stroke cylinder of equal power capacity.

In high-speed marine oil engines, which are usually worked up to their limiting rate of heat flow, the four-stroke cycle offers some advantage. On the other hand, the relatively slow speed demanded for cargo-ship engines is exceptionally favorable to the two-stroke type, since these engines operate under heat-flow conditions so moderate as to allow ample cooling of all vital parts even in the largest-sized cylinders. It is therefore readily possible to keep the bore-wall temperatures of such two-stroke engines well below the critical limits required for safe and reliable running. To further safeguard against fatigue and breakdown, it is advisable to provide for liner cylinders and such other constructive features common in high-powered oil-engine practice, so as to give the cylinder parts the requisite long life and complete immunity against cracking.

The greater frequency of impulse and the consequent more even turning effort of the two-stroke engine largely improve the speed control and reduce to a minimum the flywheel effect needed for a smooth-running marine engine.

Still another feature of the two-stroke cycle that gives promise for rapid future development, is its special adaptability to the hot-bulb type of engine.

Judging from the recent trend of marine oil-engine developments, it now appears that a combination of the constant-pressure Diesel cycle with the hot-bulb constant-volume cycle is likely to overcome the defects of both parent types. The resulting cycle is especially suited to meet American oil-engine requirements, since the lowering of the maximum Diesel working pressure to approximately that used in the automobile engine will increase the reliability of operation.

The constant-volume or explosive engine, when working with

[1] Gas Engine Expert, American-Whaley Engine Co., Boston, Mass., Mem. Am.Soc.M.E.

a compression pressure of about 250 lb. per sq. in., shows a thermal shaft efficiency but little inferior to that of the Diesel engine. By further reducing the compression to about 150 or 175 lb. per sq. in. the fuel economy of the explosive engine is but slightly sacrificed, while for a given size of crankshaft the weight and cost relations as taken upon the power-output basis show a considerable improvement as compared with the high-compression engine.

An engine operating with the combined type of cycle should be provided with an efficient timed spray valve for the fuel-oil injection, and in large engines this should preferably be of the air-injection type used for Diesel engines.

When working with such limited compression, self-ignition may best be obtained by holding a portion of the products of combustion from stroke to stroke within a water-jacketed vaporizer chamber, without, however, requiring the use of a hot plate. The trapped hot burnt gases may then be used to preheat the air that is pressed into the bulb chamber to a point where it is capable of promoting self-ignition of the injected fuel oil. This sets up a light explosion at constant volume, after which the remaining oil may be gradually fed into the power cylinder in the manner of a Diesel engine.

While the water-cooled bulb will not of itself start the engine from the cold, it does not require an external flame; instead it is only necessary to preheat the small amount of air enclosed within the vaporizer chamber, which may readily be done by means of an electric coil heater or spark plug. After the first few explosive charges are thus ignited, the required heat transfer takes place from stroke to stroke to make the engine self-igniting.

The jacketed vaporizer is especially applicable to oil engines of the single-acting type, the bulb chamber being preferably formed centrally in the cylinder head about the cylinder axis. The timed fuel valve can then be made to inject straight through the bulb chamber and directly against the hot piston head. This arrangement gives the nozzle considerable distance for proper spray formation before striking the piston top, after which the oil charge spreads out over the piston-head surface and intimately mixes with all the air throughout the combustion chamber.

Finally it is pointed out that this late development in true semi-Diesel engines is especially suited to the two-stroke-cycle engine. In the four-stroke engine considerable constructive difficulties are involved in placing the mechanically operated inlet and exhaust valves about the water-cooled vaporizer chamber. Furthermore, in a two-stroke engine the vaporizer chamber may be kept at a smaller size with respect to the piston displacement, due to the fact that the confined hot gases have less chance to cool off between power impulses.

These and other advantages previously cited would indicate that a two-stroke semi-Diesel engine along the lines discussed should in the near future find favor for the propulsion of merchant ships and be capable of fully establishing the inherent possibilities of a slow-speed oil engine for marine service.

W. D. ENNIS[1] (written). The value of this paper would be increased if the author would add particulars regarding the motors used. The mean effective pressures range from 87 to 91 lb. per sq. in., values often surpassed by stationary Diesel engines. Apparently the cylinders are the ordinary 4-cycle single-acting form, but there seems to be no statement of the fact.

A chief argument in favor of the crude-oil motor appears from Table 2, where "repeat orders" in 1916 are quoted for lines which began with this construction in 1912. What has happened since 1916?

It is to be assumed that the eight factors listed in the second paragraph are not presented as a complete list. In fact, the author refers to others, admitting a shorter life for the crude-oil motor and referring to the absence of sufficient data on maintenance costs. He also discusses what is almost an overwhelming disadvantage for any but slow-speed cargo ships, the multiplicity of cylinders. The largest cylinder in Table 2 is below 30 in. bore and develops only 333 hp. The largest plant listed is 4000 hp.

[1] Acting Professor of Mechanical Engineering, Columbia University, New York. Mem. Am.Soc.M.E.

It is doubtful whether steam can ever be eliminated in naval practice. Requirements for heating, humidifying and evaporators do not tend to decrease. It is even proposed now to use steam heat for submarines. It is difficult for internal-combustion engines to displace steam where they cannot displace it completely.

Table 1 is obviously based on coal fuel for steam. If oil fuel is used, the ratio R directly following the table becomes about 2.0 instead of 7.4.

FORREST E. CARDULLO[1] characterized the adoption of the Diesel and analogous cycles as a standard as an advance too far in the direction of theory. He said he knew of no reason why a satisfactory producer for gasifying oil could not be designed which would operate continuously at 90 per cent efficiency or even higher. He referred to the number of times a plant operating Diesel or semi-Diesel engines must be laid up in order to clean out the engines. The practical weight of experience, and of actual reliability and cheapness, he believed, was in favor of the oil-type gas-producer fuel. LEWIS H. NASH concurred in the idea of adopting the principle of gasifying oil in some type of gas producer.

HENRY B. OATLEY,[2] referring to Table 1 in which Mr. Morton presented the comparative weights of power plants in steamships and motorships, said that in the comparative installations aboard the U. S. S. *Maumee* and *Tioga*, steam and motor-driven ships, respectively, the Diesel-engine plant weighed decidedly more than the steam plant. The difficulties of getting high pressure and the limitations of superheaters of which the author spoke while discussing the heat elements of temperature range for the various types of engines existed, according to Mr. Oatley, only in the present motor designs, but he saw no difficulty in the further development of the types which have been successfully operated at pressures as high as 500 or 700 lb. per sq. in. Thus, with higher pressures and with higher degrees of steam temperature the boiler plant, in point of weight and size, would become markedly smaller, and the contrast in point of space occupied aboard the ship for the steam plant as compared to the motor plant would decrease, possibly to the point of being on a par. Mr. Oatley further criticized the argument advanced for preferring the motorship over the steam-driven ship by reason of the depreciation of the hull because of the sulphur content of coal and the amount of coal space required in the steam-driven ship, on the ground that rapid progress had been made in the utilization of oil as fuel for steam-driven ships, and that this practice would in all likelihood continue to increase.

O. C. BERRY,[3] commenting on Mr. Cardullo's suggestion of gasifying oil in some type of gas producer, mentioned that in experiments conducted at Purdue University for the purpose of finding the best means of introducing into the mixture the heat required to vaporize the liquid fuel, it had been concluded that two elements are required to get the mixture in a burnable condition. In the first place, the temperature of the mixture must be hot enough to maintain in the liquid fuel sufficient vaporizing pressure so that the fuel, once reduced to a vapor, will stay in a vaporized state and get into the cylinder as a vapor and not a liquid. The other was the time element. Because of the smallness of this time element, though the temperatures are hot enough to maintain the required temperatures, still the mixtures retain their wet condition when they arrive in the cylinder. For this reason, observed Professor Berry, the hot spot had come into automobile practice as one of the solutions for the vaporization of kerosene, and he expressed his belief that it could be applied to good advantage to the use of fuels heavier than kerosene. A properly designed hot spot, he said, would eliminate the difficulty found in gas producers, where the temperature is often so hot

[1] Engineer of Tests, Curtiss Aeroplane & Motor Corp'n., Buffalo, N. Y. Mem. Am.Soc.M.E.

[2] Chemical Engineer, Locomotive Superheater Co., New York, N. Y. Mem. Am.Soc.M.E.

[3] Professor of Mechanical Engineering, Purdue University, Lafayette, Ind.

that it is not possible to keep a high enough compression without getting preignition.

Mr. Cardullo said in reply that in mentioning the gas producer he had intended to convey the idea of the actual combustion of oil in a producer so as to form a clean, burnable mixture in the engine.

L. H. JOHNSON[1] spoke of his experience with the two-cycle semi-Deisel hot-bulb, hot-surface engine and stated that after investigating the various theories advanced to explain this type of engine he had finally formulated the following conclusion as to its operation: That the oil must be injected into the engine in the form of a spray or a mist, and if low compression is to be used, it must be sprayed against a hot surface and vaporized; then this oil gas mixes with the air compressed in the chamber and explodes by the heat of compression or the heat stored in the combustion chamber. Tests, he said, had convinced him that it is necessary for successful operation of the engine to remove the deposit of carbon or residue of material that is left in the cylinder. In the experiments to which he referred no trouble had been found in maintaining the right temperature necessary for successful operation and the main problem had been the elimination of the deposits.

DISCUSSIONS OF MR. ARNOLD'S PAPER ON A SUGGESTED FORMULA FOR RATING KEROSENE ENGINES

HARRY F. SMITH[2] thought that it would be altogether out of place to attempt to create any arbitrary standard of cubic-inch displacement for the determination of the horsepower of the kerososene-oil engine. He said he knew of tests recently made on substantially identical kerosene-oil engines in which the b.hp. developed differed by 100 per cent, due to change in cylinder design. That meant that the thermal efficiency of one engine was 100 per cent better than the other. It seemed to him, therefore, that the manufacturer who was in a position to double the thermal efficiency of the kerosene oil engine ought to be entitled to whatever benefits might accrue thereby, and not be handicapped by the action of the Society or of state legislatures in rating his engine at a certain horsepower according to its size or the number of pounds of cast iron put into it.

STAFFORD MONTGOMERY[3] inquired whether the rating of kerosene engine builders from 8000 to 20,000 cu. in. per b.hp. was limited to kerosene engines or whether it applied also to gasoline engines. This question was referred to the meeting by the chairman.

FREDRIK OTTESEN[4] protested against manufacturers of large gas engines having to adopt the formula set forth in Mr. Arnold's paper.

WILLIAM T. MAGRUDER remarked that in the Ohio State University School of Aeronautics they had formulated a statement which was fairly accurate, that instead of using 13,000 or 14,000, 10,000 cu. in. represented quite closely the horsepower of a Curtiss aeroplane engine up to 100 per cent capacity, and increased speed after that did not give correspondingly increased horsepower. He said that the horsepower of a steam tractor is unknown until tested for the reason that its overload capacity is not like that of a boiler, one or two or three hundred per cent, but from four to five hundred per cent; and that in tests perfomed at the laboratories of the university tractors nominally rated at 20 hp. gave over 100 hp. and kept it up; on the other hand, in actual tests of kerosene and gasoline tractors on blocks, either in field work or in comparative b.hp. tests, many of the tractors fail to operate at their rated horsepower and not even their own experts could always get from them what the nameplates indicated they should deliver. Such being the conditions in practice, it appeared to him that by the standardization of horsepower, misunderstandings arising from the erroneous interpretation of the discrepancy between rated and actual horsepower could be avoided. He further observed that the question was bound to be soon taken up by the various legislatures and, as Mr. Arnold said in his paper, the conditions at present existing in the gas tractor and the kerosene tractor would be duplicated in the automobile if the Society did not take prompt and effective steps to translate the idea of a horsepower so as to make it intelligible to the average man who knows nothing about machinery or about mechanics.

JOHN CHUCAN[1] assented to the remarks made by Professor Magruder and asserted that he had actually used for several years the formula proposed by Mr. Arnold and had found it to be very conservative. The formula, he said, was intended only for tractors and not for stationary engines or any other engines.

DISCUSSION OF PROFESSOR BERRY'S PAPER ON STANDARDS OF CARBURETOR PERFORMANCE

FORREST E. CARDULLO remarked that the carburetor design was intimately connected with the structural details of the engine, with the form of the admission parts, and especially with the form of the manifold. The real problem of carburetor design, as he saw it, was to get the combination of a carburetor and inlet port in an engine which would give a uniformly suspended mixture of minute droplets in air at the instant the spark fires the charge. In order to get at this, Professor Berry recommended the application of certain standards to the testing of the carburetor in order to determine the uniformity of the mixture under operating conditions of the engine. But this would not lead, say, to the knowledge of the best kind of a combination carburetor, manifold and engine which would enable an automobile to climb a good stiff hill at ten or fifteen miles per hour, and at the same time give a speed of three miles per hour in a crowded traffic street and a speed of fifty miles per hour on a smooth, clear road.

Mr. Cardullo further observed that a rich mixture could be secured at the instant of acceleration more by properly designing the form of the manifold than by providing methods for increasing the mixture. Also that by reason of the separator action of the manifold it would be impossible to get a representative sample of the mixture entering the cylinder, and he believed the proper thing to do would be to analyze the exhaust of each cylinder for the proportion of carbon dioxide in order to determine whether each cylinder was getting its due proportion of gasoline in the mixture provided.

THOMAS J. LITLE, JR.,[2] observed that in automobile practice many difficulties are encountered which do not occur in stationary engine work. With reference to the statement in the paper that the best performance is obtained with a temperature of 80 deg., he preferred to take the temperature of the mixture entering the block, after it passes through the carburetor intake manifold. He claimed that the temperature of the charge as it entered the block, after it passed through the carburetor and intake manifold, was the controlling factor in motor performance. He suggested as a future line of research work tapping into the intake passage just at the end of the supply pipe and analyzing a sample of the mixture taken at that point. To a question of Chairman Magruder inquiring how that sample of air and gasoline vapor was going to be obtained, Mr. Litle explained that he had succeeded in drawing it off by lifting the valve of a tall gasometer with a long water still.

In closing the discussion Professor Berry called attention to the fact that a temperature of 300 deg. on the air in the carburetor had been used in all of the tests reported in the paper. He had

(*Continued on page 718*)

[1] Gen. Mgr., Anderson Foundry and Machine Works, Anderson, Ind. Mem. Am.Soc.M.E.
[2] Secretary, General Manager, Smith Gas Engineering Co., Dayton, Ohio. Mem. Am.Soc.M.E.
[3] Consulting Industrial and Production Engineer, Chicago, Ill. Jun. Am.Soc.M.E.
[4] Chemical Engineer, Gas Engine Department, Mesta Machine Co., Pittsburgh, Pa. Mem. Am.Soc.M.E.

[1] Goodwin Car and Manufacturing Co., Inc., Chicago, Ill. Assoc. Mem. Am.Soc.M.E.
[2] Research Engineer, Lincoln Motor Company, Detroit, Mich.

WORK OF THE BOILER CODE COMMITTEE

FOR over two years, a sub-committee of the Boiler Code Committee, known as the Sub-Committee on Railway Locomotive Boilers, has been engaged in formulating a set of rules for the construction of railway locomotive boilers, to be known as Part I, Section III, of the A. S. M. E. Boiler Code. The necessity for such an addition to the Boiler Code arose from the fact that, while the boilers of locomotives operated on railways engaged in interstate service are covered by the construction and inspection rules of the Interstate Commerce Commission, there was found to be a vast mileage of industrial and short-line railroads in operation in the various states, which by virtue of their location, are not subject to the Interstate requirements.

As a result of calls for a Code to cover the construction of boilers of this class, the Sub-committee on Railway Locomotive Boilers was appointed in 1916, and great care was taken to select for the membership of this Sub-committee men particularly qualified for the work. The Sub-committee of the Boiler Code Committee on Railway Locomotive Boilers consists of the following members:

F. H. CLARK, *Chairman*
F. J. COLE
ALEX. C. HUMPHREYS
S. F. JETER
WM. F. KIESEL, JR.
H. H. VAUGHAN.

While the work of this Sub-Committee was interrupted somewhat during the period of the war, its investigations were completed in the earlier part of the year and a preliminary report was submitted to the Boiler Code Committee in April. The preliminary report was next printed and distributed at the Spring Meeting at Detroit in June where it was discussed and upon motion, the preliminary report of the Committee was accepted by the meeting. The report is here published for the information of the membership. Any one desiring to discuss the preliminary report is requested to address the Secretary of the Boiler Code Committee, 29 West Thirty-Ninth Street, New York, N. Y.

A. S. M. E. BOILER CODE

PART I—SECTION III

PRELIMINARY REPORT ON RULES FOR THE CONSTRUCTION OF BOILERS OF LOCOMOTIVES WHICH ARE NOT SUBJECT TO FEDERAL INSPECTION AND CONTROL[1]

NOTE: When this Section is incorporated in the Boiler Code, it will be desirable to change the word "STATIONARY," to "STEAM," at the top of front cover and of the title page and on page 3 of the Code. Also the sentence in italics on page 3 will be changed to read, as follows:

"*These rules do not apply to boilers which are subject to Federal inspection and control.*"

Also to insert, after bracket in line beginning Part I, the following:

"SECTION III—LOCOMOTIVE BOILERS"

SELECTION OF MATERIALS

L—1 (X—1) Specifications are given in the Rules for Power Boilers, Pars. 23 to 178, for the important materials used in the construction of boilers, and where so given, the materials herein mentioned shall conform thereto, except as noted in Par. L—18.

L—2 (X—2) Steel plates for any part of a boiler when exposed to the fire or products of combustion, and under pressure, *excepting front tube sheets*, shall be of firebox quality as designated in the Specifications for Boiler Plate Steel.

L—3 (3) Steel plates for any part of a boiler, where firebox quality is not specified, when under pressure, shall be of firebox or flange quality, as designated in the Specifications for Boiler Plate Steel.

L—4 (4) Braces, when welded, shall be of wrought iron of the quality designated in the Specifications for Refined Wrought Iron Bars.

L—5 (5) Manhole and handhole covers and other parts subjected to pressure, and braces and lugs when made of steel plate, shall be of firebox or flange quality, as designated in the Specifications for Boiler Plate Steel.

L—6 (6) Steel bars for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

L—7 (X—7) Staybolts shall be of iron of the quality designated in the Specifications for Staybolt Iron.

L—8 (8) Rivets shall be of steel or iron of the quality designated in the Specifications for Boiler Rivet Steel, or in the Specifications for Boiler Rivet Iron.

L—9 (X—12) Throttle and throttle pipe, dry pipe or dry pipe ring, tee head, superheater header and steam pipes to cylinders, may be of cast iron.

L—10 (13) Water-leg and door-frame rings shall be of wrought iron or steel, or cast steel of Class A or Class B grade, as designated in the Specifications for Steel Castings. The OG or other flanged construction may be used as a substitute in any case.

ULTIMATE STRENGTH OF MATERIAL USED IN COMPUTING JOINTS

L—11 (14) In determining the maximum allowable working pressure, the tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the mimimum of the stipulated range, or 55,000 lb. per sq. in. for all steel plates, except for special grades having a lower tensile strength.

TABLE 1 MINIMUM THICKNESS OF BUTT STRAPS

Thickness of Shell Plates, Inches	Minimum Thickness of Butt Straps, Inches	Thickness of Shell Plates, Inches	Minimum Thickness of Butt Straps, Inches
1/4	1/4	11/16	7/16
5/16	1/4	3/4	7/16
3/8	1/4	13/16	1/2
7/16	1/4	7/8	1/2
1/2	1/4	15/16	9/16
9/16	5/16	1	9/16
5/8	5/16	1 1/8	5/8
11/16	3/8	1 1/4	3/4
3/4	3/8		
13/16	7/16		

L—12 (15) The resistance to crushing of steel plate shall be taken at 95,000 lb. per sq. in. of cross-sectional area.

L—13 (16) In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area used in the computations shall be that of the rivet shank after driving.

[1] Numbers in parentheses at the beginning of paragraphs indicate paragraphs in A.S.M.E. Boiler Code (Edition of 1918) to which these paragraphs correspond.

The letters X, Y and Z indicate as follows: X—Rules of present Boiler Code modified; Y—New rules; Z—Interstate Commerce Commission rules.

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Minimum Thickness of Plates and Tubes

L—14 (17) The minimum thickness of any boiler plate under pressure shall be ¼ in.

L—15 (18) The minimum thickness of shell plates, and dome plates after flanging, shall be as follows:

When the Inside Diameter of Shell is			
36 in. or Under	Over 36 in. to 54 in.	Over 54 in. to 72 in.	Over 72 in.
¼ in.	7/16 in.	9/16 in.	½ in.

L—16 (19) The minimum thickness of butt straps for double strap joints shall be as given in Table 1. Intermediate values shall be determined by interpolation. For plate thicknesses exceeding 1¼ in., the thickness of the butt straps shall not be less than two-thirds of the thickness of the plate.

L—17 (X—20) The minimum thickness of tube sheets for locomotive boilers, shall be as follows:

When Diameter of Tube Sheet is		
42 in. or Under	Over 42 in. to 54 in.	Over 54 in.
3/8 in.	7/16 in.	½ in.

L—18 (X—22) The minimum gage thickness of tubes or flues exposed to the products of combustion on the inside shall be as specified in Table 2 for the various pressures and outside diameters given.

The gage thickness in Table 2 is that measured by the B. W. gage with a permitted variation in thickness at any section not varying more than 10 per cent from that specified, except at the weld of lap-welded tubes where an additional thickness of 0.015 in. shall be allowed. In the case of superheater tubes which are expanded, the gage of the expanded end may be 1½ gages lighter and the swaged end two gages heavier than the gage thickness.

TABLE 2 MINIMUM THICKNESS OF WALLS OF FIRE TUBES

Outside Diameter, In	Maximum Allowable Working Pressure, Lb. per Sq. In.				
	160	180	200	225	250
1½	13	13	12	..	..
1¾	13	12	12	..	..
2	12	12	12	11	11
2¼	12	12	12	11	11
2½	12	12	11	11	11
3	12	11	11	11	10
3½	11	11	11	10	10
4	11	10	10	10	9
4½	10	10	10	9	9
5	10	9	9	9	8
5½	9	9	9	8	8
6	9	9	8	8	7

L—19 (Y) The minimum thickness of walls of brick arch tubes shall be determined by the following formula:

$$t = \frac{PD}{16{,}000} + \tfrac{1}{8} \text{ in.}$$

where P = allowable boiler pressure, lb. per sq. in.
t = thickness of walls, in.
D = outside diameter, in.

Construction and Maximum Allowable Working Pressure for Boilers of Locomotives

L—20 (179) The maximum allowable working pressure is that at which a boiler may be operated as determined by employing the factors of safety, stresses and dimensions designated in these rules.

No boiler shall be operated at a higher pressure than the maximum allowable working pressure, except when the safety valve or valves are blowing, at which time the maximum allowable working pressure shall not be exceeded by more than six per cent.

Wherever the term "Maximum Allowable Working Pressure" is used herein, it refers to gage pressure, or the pressure above the atmosphere, in pounds per square inch.

L—21 (X—180) The maximum allowable working pressure on the shell of a boiler shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon, as provided for in Specifications for Boiler Plate Steel, the efficiency of the longitudinal joint, the inside diameter of the course, and the factor of safety.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working presure, lb. per sq. in.}$$

where
TS = ultimate tensile strength stamped on shell plates, as provided for in Specifications for Boiler Plate Steel, lb. per sq. in.
t = minimum thickness of shell plates in weakest course, in.
E = efficiency of longitudinal joint.
R = inside radius of the weakest course of the shell, in.
FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress. For new constructions covered in Part III, FS in the above formula = 4.

Boiler Joints

L—22 (181) The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. In the case of a riveted joint this is determined by calculating the breaking strength of a unit section of the joint, considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of a length equal to that of the section considered. (See Appendix, Pars. 410 to 416, Power Boilers, for detailed methods and examples.)

L—23 (X—182) The distance between the center lines of any two adjacent rows of rivets, or the "back pitch" measured at right angles to the direction of the joint, shall have the following minimum values:

a If $\frac{P}{D}$ is 4 or less, the minimum value shall be $1.75D$;

b If $\frac{P}{D}$ is over 4, the minimum value shall be:

$$1.75\,D + 0.1\,(P - 4\,D)$$

where
P = pitch of rivets in outer row where a rivet in the inner row comes midway between two rivets in the outer row, in.
P = pitch of rivets in the outer row less pitch of rivets in the inner row where two rivets in the inner row come between two rivets in the outer row, in. (It is here assumed that the joints are of the usual construction where the rivets are symmetrically spaced.)
D = diameter of the rivet holes, in.

L—24 (X—183) On longitudinal joints the distance from the centers of rivet holes to the edges of the plates, except rivet holes in the ends of butt straps, shall be not less than one and one-third times the diameter of the rivet holes.

L—25 (X—184) The strength of circumferential joints of boilers shall be at least 50 per cent of that required for the longitudinal joints of the same structure.

L—26 (187) The longitudinal joints of a shell which exceeds 36 in. in diameter, shall be of butt and double-strap construction.

This rule does not apply to the portion of a boiler shell which is stayed to the firebox or combustion chamber.

L—27 (188) The longitudinal joints of a shell which does not exceed 36 in. in diameter, may be of lap-riveted construction; but the maximum allowable working pressure shall not exceed 100 lb. per sq. in.

L—28 (X—190) With butt and double-strap construction longi-

tudinal joints of any length may be used, provided the tension test specimens are so cut from shell plates and butt-strap plates that their lengthwise direction is parallel with the circumferential seams of the boiler, and the tests meet the standards prescribed in the Specifications for Boiler Plate Steel.

L—29 (191) Butt straps and the ends of shell plates, forming the longitudinal joints shall be rolled or formed by pressure, not blows, to the proper curvature.

L—30 (X—194) The longitudinal joint of a dome shall be of butt and double-strap construction or made without a seam of one piece of steel pressed into shape, and its flange shall be double-riveted to the boiler shell, unless the dome be less than 24 in. in diameter, in which case the longitudinal joint may be of the lap type, and its flange may be single-riveted to the boiler shell provided the maximum allowable working pressure on such a dome does not exceed 160 lb. per sq. in., and is computed with a factor of safety not less than 8.

(Y) When boiler shells are cut to apply steam domes or manholes, the amount of metal in flange and liner, if used, must provide strength equivalent to that of the metal removed multiplied by the efficiency factor of the longitudinal seams. A height of vertical flange equal to three times the thickness of flange shall constitute flange reinforcement, using net area after rivet holes are deducted.

BRACED AND STAYED SURFACES

L—31 (X-199) The maximum allowable working pressure for various thicknesses of braced and stayed flat plates and those which by these Rules require staying as flat surfaces with braces or stays of uniform diameter symmetrically spaced, shall be calculated by the formula:

$$P = C \times \frac{T^2}{p}$$

where

P = maximum allowable working pressure, lb. per sq. in.
T = thickness of plate in sixteenths of an inch
p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal, vertical or inclined, in.
C = 112 for stays screwed through plates not over $\frac{7}{16}$ in. thick with ends riveted over
C = 120 for stays screwed through plates over $\frac{7}{16}$ in. thick with ends riveted over
C = 135 for stays screwed through plates and fitted with single nuts outside of plate
C = 150 for stays with heads not less than 1.3 times the diameter of the stays, screwed through plates or made a taper fit and having the heads formed on the stays before installing them and not riveted over, said heads being made to have a true bearing on the plate.

If flat boiler plates not less than $\frac{3}{8}$ in. thick are strengthened with doubling plates securely riveted thereto and having a thickness of not less than $\frac{2}{3}$ T, then the value of T in the formula shall be three-quarters of the combined thickness of the boiler plate, and doubling plates, but not more than one and one-half times the thickness of the boiler plate, and the values of C given above may also be increased 15 per cent.

When two sheets are connected by stays and but one of these sheets requires staying, the value of C is governed by the thickness of the sheet requiring staying.

In curved sheets of a combustion chamber, half of which is a semicircle (radius R, in.) an increased pitch (p_1, in.) based on the following formula, may be used:

$$p_1 = p\sqrt{\frac{PR}{PR - 250T}}$$

L—32 (X-200) The ends of screwed staybolts shall be riveted over or upset by equivalent process. The outside ends of solid staybolts 8 in. and less in length shall be drilled with a hole at least $\frac{5}{16}$ in. diameter to a depth extending at least $\frac{1}{2}$ in. beyond the inside of the plates, or hollow staybolts may be used. Solid staybolts over 8 in. long and flexible staybolts of either the jointed or ball and socket type need not be drilled.

Staybolts behind brickwork, frame braces, or grate bearers shall have holes at least $\frac{3}{16}$ in. diameter for entire length, which must be kept open at all times.

L—33 (201) When channel irons or other members are securely riveted to the boiler heads, the stress on such members shall not exceed 12,500 lb. per sq. in. In computing the stress the section modulus of the member shall be used without addition for the strength of the plate. This spacing of the rivets over the supported surface shall be in conformity with that specified for staybolts.

If the outstanding legs of the two members are fastened together so that they act as one member in resisting the bending action produced by the load on the rivets attaching the members to the head of the boiler, and provided that the spacing of those rivets attaching the members to the head is approximately uniform, the members may be computed as a single beam uniformly loaded and supported at the points where the through braces are attached.

L—34 (202) The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

L—35 (X-203) *a* The maximum spacing between centers of rivets or between the edges of tube holes and the centers of rivets attaching the crowfeet of braces to the braced surface, shall be determined by the formula in Par. L—31, using 135 for the value of C.

b The maximum distance between the edges of tube holes and the centers of other types of stays shall be determined by the formula in Par. L—31, using the value of C given for the thickness of plate and type of stay used.

c The maximum spacing between the inner surface of the shell and lines parallel to the surface of the shell passing through the centers of the rivets attaching the crowfeet of braces to the head shall be determined by the formula in Par. L—31, using 175 for the value of C.

d The maximum distance between the inner surface of the shell and the centers of braces of other types shall be determined by the formula in Par. L—31, using a value of C equal to 1.3 times that value of C, which applies to the thickness of plate and type of stay as therein specified.

e In applying these Rules and those in Par. L—31 to a head or plate having a manhole or reinforced opening, the spacing applies only to the plate around the opening and not across the opening.

L—36 (Y) *a* When the edge of a stayed plate is flat and is fastened by riveting, the distance from the center line of the rivets to a line through the centers of the nearest row of stays may be made to equal the pitch of the stays as given in Table 3 plus twice the thickness of the plate.

b When the edge of a flat stayed plate is flanged and riveted, the distance from the center of the outermost stays to the inside of the supporting flange should not exceed the pitch of the stays from the table plus the inside radius of the flange.

L—37 (X-204) Where values for screwed stays with ends riveted are required for conditions not given in Table 3, they may be computed from the formula in Par. L—31 and used, provided the pitch does not exceed 8½ in.

L—38 (206) The distance between the edges of the staybolt holes may be substituted for p for staybolts adjacent to a furnace door or other boiler fitting, tube hole, handhole or other opening.

L—39 (X-208) The diameter of a screw stay shall be taken at the bottom of the thread, or at the body of the bolt between the threads—whichever is the lesser.

L—40 (X-209) The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except when the stays are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall be computed as well as in the solid part and the lower value used.

L—41 (210) Holes for screw stays shall be drilled full size or punched not to exceed ¼ in. less than full diameter of the hole for plates over $\frac{5}{16}$ in. in thickness, and ⅛ in. less than the full diameter of the hole for plates not exceeding $\frac{5}{16}$ in. in thickness,

TABLE 3 MAXIMUM ALLOWABLE PITCH, IN INCHES, OF SCREWED STAYS, ENDS RIVETED OVER

Pressure Lb. per Sq. In.	Thickness of Plate, In.						
	7/16	1/2	9/16	5/8	11/16	3/4	13/16
	Maximum Pitch of Staybolts, In.						
100	5 1/4	6 3/8	7 3/8	...	...	...	...
110	5	6	7	8 3/8	...	...	...
120	4 3/4	5 3/4	6 3/4	8	...	...	...
125	4 3/4	5 5/8	6 5/8	7 3/4	...	...	...
130	4 5/8	5 1/2	6 1/2	7 5/8	...	...	...
140	4 1/2	5 3/8	6 1/4	7 3/8	8 3/8	...	...
150	4 1/4	5 1/8	6	7 1/8	8	...	...
160	4 1/8	5	5 7/8	6 7/8	7 3/4	...	...
170	4 1/8	4 7/8	5 5/8	6 3/4	7 1/2	8 3/8	...
180	3 11/16	4 3/4	5 1/2	6 1/2	7 3/8	8 1/8	...
190	3 11/16	4 5/8	5 3/8	6 3/8	7 1/8	7 7/8	...
200	3 11/16	4 1/2	5 1/4	6 1/8	7	7 3/4	8 1/2
225	3 1/2	4 1/4	4 7/8	5 7/8	6 1/2	7 1/4	8
250	...	4	4 5/8	5 1/2	6 1/4	6 7/8	7 5/8
300	...	...	4 1/4	5	5 5/8	6 1/4	7

and then drilled or reamed to the full diameter. The holes shall be tapped fair and true, with a full thread.

L—42 (211) The ends of steel stays upset for threading shall be thoroughly annealed.

L—43 (X—212) *a* The maximum allowable working pressure for any curved stayed surface subject to internal pressure shall be obtained by the two following methods, and the minimum value obtained shall be used:

First, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays. To this pressure there shall be added the pressure secured by the formula for braced and stayed surfaces given in Par. L—31, using 70 for the value of C.

Second, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays. To this pressure there shall be added the pressure corresponding to the strength of the stays for the stresses given in Table 4, each stay being assumed to resist the steam pressure acting on the full area of the external surface supported by the stay.

TABLE 4 MAXIMUM ALLOWABLE STRESSES FOR STAYS AND STAYBOLTS

Description of Stays	Stresses, Lb. Per Sq. In.	
	For lengths between supports not exceeding 120 diameters	For lengths between supports exceeding 120 diameters
a Unwelded or flexible stays less than twenty diameters long, screwed through plates with ends riveted over	7500	....
b Hollow steel stays less than 20 diameters long, screwed through plates with ends riveted over	8000	....
c Unwelded stays and unwelded portions of welded stays, except as specified in line *a* and line *b*	9500	8500
d Welded portions of stays	6000	6000

b The maximum allowable working pressure for a stayed wrapper sheet of a locomotive-type boiler shall be determined by the two methods given above and by the method which follows, and the minimum value obtained shall be used:

$$P = \frac{13{,}500t \times E}{R - s\Sigma \sin \alpha}$$

in which

α = angle any crown stay makes with vertical axis of boiler

$\Sigma \sin \alpha$ = summuated value of $\sin \alpha$ for all crown stays considered in one transverse plane and on one side of vertical axis of boiler

s = transverse spacing of crown stays in crown sheet, in.

E = minimum efficiency of wrapper sheet through joints or stay holes

t = thickness of wrapper sheet, in.

R = radius of wrapper sheet, in.

P = working pressure of boiler, lb. per sq. in.

13,500 = allowable stress, lb. per sq. in.

L—44 (X—213) A segment of a head shall be stayed by through, diagonal, crowfoot or gusset stays.

L—45 (X—214) The area of a segment of a head to be stayed shall be the area enclosed by lines drawn 2 in. from the tubes and at a distance d from the shell as shown in Figs. 15 and 16, Part I, Section I. The value of d used may be the larger of the following values:

(1) d = the outer radius of the flange, not exceeding 8 times the thickness of the head

(2) $$d = \frac{5 \times T}{\sqrt{P}}$$

where

d = unstayed distance from shell in inches

T = thickness of head in sixteenths of an inch

P = maximum allowable working pressure in lb. per sq. in.

(Y) The feet for braces to back head and front tube sheet should be distributed so as not to concentrate the stress on any one section; preferably a proportion of the braces should be attached to the second course from the back head or front tube sheet.

(Y) No supporting value shall be assigned to the stiffness of inside liner plates on flat surfaces, except as provided in L—31.

L—46 (X—221) In calculating stresses for diagonal stays in Pars. L—47-48 the angularity of the stays must be taken into account.

L—47 (X—223) All rivet and pin holes shall conform to the requirements in Par. L—54 and the pins shall be made a neat fit. To determine the sizes that shall be used, proceed as follows:

1 Determine the "required cross-sectional area of the brace" by first computing the total load to be carried by the brace, and dividing the total load by the values of stresses given in Table 4.

2 Design the body of the brace so that the cross-sectional area shall be at least equal to the "required cross-sectional area of the brace."

3 Make the area of pins to resist double shear at least three-quarters of the "required cross-sectional area of the brace."

4 Make the combined cross-section of the eye at the side of the pin (in crowfoot braces) at least 25 per cent greater than the "required cross-sectional area of the brace."

5 Make the cross-sectional areas through the blades of diagonal braces where attached to the shell of the boiler at least equal to the required rivet section; that is, at least equal to one and one-quarter times the "required cross-sectional area of the brace."

6 Design each branch of a crowfoot to carry two-thirds the total load on the brace.

7 Make the net sectional areas through the sides of the crowfoot, tee irons, or similar fastenings at the rivet holes at least equal to the required rivet section; that is, at least equal to one and one-quarter times the "required cross-sectional area of the brace."

8 Make the combined cross-sectional area of the rivets at each end of the brace at least one and one-quarter times the "required cross-sectional area of the brace."

L—48 (X—224) Gusset stays when constructed of triangular

web plates secured to single or double angle bars along the two sides at right angles shall have a cross-sectional area (in a plane at right angles to the longest side and passing through the intersection of the two shortest sides) not less than 10 per cent greater than would be required for a diagonal stay to support the same surface, assuming the diagonal stay is at the same angle as the longest side of the gusset plate.

L—49 (X—230) Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$\text{Maximum allowable working pressure} = \frac{C \times d^2 \times t}{(W - P) \times D \times W}$$

where

W = extreme distance between supports, in.
P = pitch of supporting bolts, in.
D = distance between girders from center to center, in.
d = depth of girder, in.
t = thickness of girder, in.
C = 7000 when the girder is fitted with one supporting bolt
C = 10,000 when the girder is fitted with two or three supporting bolts
C = 11,000 when the girder is fitted with four or five supporting bolts
C = 11,500 when the girder is fitted with six or seven supporting bolts
C = 12,000 when the girder is fitted with eight or more supporting bolts

Example: Given $W = 34$ in., $P = 7.5$ in., $D = 7.75$ in., $d = 7.5$ in., $t = 2$ in.; three stays per girder, $C = 10{,}000$; then substituting in formula:

$$\text{Maximum allowable working pressure} = \frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34 - 7.5) \times 7.75 \times 34} = 161.1 \text{ lb. per sq. in.}$$

(Y) In boilers with crown bars supported on firebox side sheets, and sling stays, the sling stays shall be considered as carrying the entire load.

L—50 (248) *Tubes.* Tube holes shall be drilled full size from the solid plate, or they may be punched at least ½ in. smaller in diameter than full size, and then drilled, reamed or finished full size with a rotating cutter.

L—51 (249) The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

L—52 (X—250) The ends of the tubes shall be substantially rolled and beaded, or rolled and welded, at the firebox or combustion-chamber end, and rolled at the smokebox end; 10 per cent of the flues at the smokebox shall be beaded.

Riveting

L—53 (253) All rivet holes and staybolt holes and holes in braces and lugs shall be drilled full size or they may be punched not to exceed ¼ in. less than full diameter for material over $\frac{5}{16}$ in. in thickness, and ⅛ in. less than full diameter for material not exceeding $\frac{5}{16}$ in. in thickness, and then drilled or reamed to full diameter. Plates, butt straps, braces, heads and lugs shall be firmly bolted in position by tack bolts for drilling or reaming all rivet holes in boiler plates, except those used for the tack bolts.

L—54 (254) After drilling or reaming rivet holes the plates and butt straps shall be separated, the burrs and chips removed, the plates and butt straps reassembled metal to metal with barrel pins fitting the holes, and with tack bolts.

L—55 (X—255) Rivets shall be of sufficient length to completely fill the rivet holes and form heads at least equal to those shown in Fig. 20, Part I, Section I.

L—56 (256) Rivets shall be machine-driven wherever possible, with sufficient pressure to fill the rivet holes, and shall be allowed to cool and shrink under pressure. Barrel pins fitting the holes and tack bolts to hold the plates firmly together shall be used. A rivet shall be driven each side of each tack bolt before removing the tack bolt.

L—57 (257) The calking edges of plates, butt straps and heads shall be beveled to an angle not less than 70 deg. to the plane of the plate, and as near thereto as practicable. Every portion of the sheared surfaces of the calking edges of plates, butt straps and heads shall be planed, milled or chipped to a depth of not less than ⅛ in. Calking shall be done with a round-nosed tool.

L—58 (X—265) A locomotive boiler shall have washout handholes or screw plugs, as follows: One at each corner of firebox just above mud ring; one in back head over fire door; one or more on each side of roof sheet above the level of crown sheet, which shall be staggered on opposite sides; one or more in barrel of boiler; and one or more in back head above crown sheet.

(Y) Screw plugs must have at least four full threads in the sheet, including reinforcement, if such is used.

L—59 (Y—268) All holes for injector checks, whistle, and safety valves when screwed into boiler, and all holes in boiler barrel, firebox, roof sheet, and all unstayed surfaces when diameter of the hole is over 3¼ in. and exceeds 4½ times the thickness of the plate, must be reinforced with a liner or flange riveted to the boiler.

The thickness of the liner or flange must be at least 75 per cent of the thickness of the plate. The rivets must have a shearing strength of at least 52 per cent of the tensile strength of the metal removed.

Safety Valves

L—60 (Z—269) Every locomotive boiler shall be equipped with at least two safety valves, the capacity of which shall be sufficient to prevent, under any conditions of service, an accumulation of pressure more than 6 per cent above the specified boiler pressure.

L—61 (Z—271) Safety valves shall be set to pop at pressures not exceeding 6 b. above the working steam pressure. When setting safety valves, two steam gages shall be used, one of which must be so located that it will be in full view of the person engaged in setting such valves; and if the pressure indicated by the gages varies more than 3 lb., they shall be removed from the boiler, tested and corrected before the safety valves are set. Gages shall in all cases be tested immediately before the safety valves are set or any change made in the setting. When setting safety valves, the water level in the boiler shall not be above the highest gage cock.

L—62 (X—272) Safety valves may have the seat and bearing surface of the disk inclined at any angle between 45 deg. and 90 deg. to the center line of the spindle. The valves shall be rated at a pressure 3 per cent in excess of that at which the valve is set to blow.

All safety valves shall be so constructed that no detrimental shocks are produced through the operation of the valve.

L—63 (273) Each safety valve shall be plainly marked by the manufacturer. The markings may be stamped or the body, cast on the body, or stamped or cast on a plate or plates permanently secured to the body, and shall contain the following:

a The name or identifying trademark of the manufacturer
b The nominal diameter
c The steam pressure at which it is set to blow
d Blow down, or difference between the opening and closing pressures
e The weight of steam discharged in pounds per hour at a pressure 3 per cent higher than that for which the valve is set to blow
f A.S.M.E. Std.

L—64 (X—275) Safety-valve capacity may be checked in the following manner; and, if found sufficient, additional capacity need not be provided:

By making an accumulation test with fire in good bright condition, and all steam exits closed, and fire forced under these conditions, the safety valves should relieve boiler and not allow an excess pressure of more than 6 per cent above the working pressure.

L—65 (X—278) Each safety valve shall have full-sized direct connection to the boiler.

L—66 (X-279) If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit.

L—67 (280) When a boiler is fitted with two or more safety valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined area of all of the safety valves with which it connects.

L—68 (X-283) The seats and disks of safety valves shall be of non-ferrous material.

L—69 (284) Springs used in safety valves shall not show a permanent set exceeding $\frac{1}{32}$ in. ten minutes after being released from a cold compression test closing the spring solid. The spring shall be so constructed that the valve can lift from its seat at least one-tenth the diameter of the seat before the coils are closed or before there is other interference.

L—70 (285) The spring in a safety valve shall not be used for any pressure more than 10 per cent above or below that for which it was designed.

L—71 (287) When the valve body is marked with the letters A.S.M.E. Std. as required by Par. L—64, this shall be a guarantee by the manufacturer that the valve conforms to the details of construction herein specified.

L—72 (X-290) Every boiler shall have proper outlet connections for the required safety valve or valves, independent of any other steam outlet connection or of any internal pipe in the steam space of the boiler, the area of opening to be at least equal to the aggregate nominal area of all of the safety valves to be attached thereto.

L—73 (X-291) Each boiler should have at least one water glass and lamp and two gage cocks for boilers 36 in. in diameter and under, and three gage cocks for boilers over 36 in. in diameter.

(Y) The lowest gage cock and the lowest reading of water glass shall not be less than 2 in. above the highest point of crown sheet on boilers 36 in. in diameter and under, and 3 in. for boilers over 36 in. in diameter. These are minimum dimensions, and on large locomotives, and those operating on steep grades, the height should be increased if necessary to compensate for change of water level on descending grades.

L—74 (X-292) No water-glass connection shall be fitted with an automatic shut-off valve.

L—75 (Z-296) Every boiler shall have at least one steam gage which will correctly indicate the working pressure. Care must be taken to locate the gage so that it will be kept reasonably cool, and can be conveniently read by the engineman.

Every gage shall have a siphon of ample capacity to prevent steam entering the gage. The pipe connection shall enter the boiler direct, and shall be maintained steam-tight between boiler and gage. The siphon shall be of brass, copper or bronze composition.

L—76 (297) The dial of the steam gage shall be graduated to not less than 1½ times the maximum allowable working pressure on the boiler.

L—77 (298) Each boiler shall be provided with a valved connection not less than ¼-in. pipe size for attaching a test gage when the boiler is in service, so that the accuracy of the boiler steam gage can be ascertained.

Fittings and Appliances

L—78 (X-311) Locomotive boilers are to be equipped with at least one blow-off cock located at the lowest water space practicable, directly connected to the boiler, either with screw connections or flanged.

L—79 (X-315) Each boiler shall be equipped with two injectors, or two pumps, or one injector and one pump, with separate delivery pipes connected to the injector checks. The water shall be delivered to the boiler at a point nearer the front than the back flue sheet.

Hydrostatic Tests

L—80 (X-329) After a boiler has been completed, it shall be subjected to a hydrostatic test of 25 per cent above the maximum allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 6 per cent.

L—81 (330) During a hydrostatic test, the safety valve or valves shall be removed, or each valve disk shall be held to its seat by means of a testing clamp, and not by screwing down the compression screw upon the spring.

L—82 (X-331) In laying out shell plates, furnace sheets and heads in the boiler shop, care shall be taken to leave at least one of the stamps, specified in Par. 36 of Part I, Section I, so located as to be plainly visible when the boiler is completed. Butt straps shall have at least a portion of such stamps visible, sufficient for identification when the boiler is completed.

L—83 (X-332) Each boiler shall conform in every detail to these Rules, and shall be distinctly stamped with the symbol as shown in Fig. 23, Part I, Section I, denoting that the boiler was constructed in accordance therewith.

After obtaining the stamp to be used when boilers are to be constructed to conform with the A.S.M.E. Boiler Code, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company which is authorized to do a boiler insurance business in the state in which the boiler is built and in the state in which it is to be used, if known, is to be notified that an inspection is to be made and he shall inspect such boilers during construction and after completion. At least two inspections shall be made, one before reaming rivet holes and one at the hydrostatic test. In stamping the boiler after completion, if built in compliance with the Code, the builder shall stamp the boiler in the presence of the inspector, after the hydrostatic test, with the A.S.M.E. Code stamp, the builder's name and the serial number of the manufacturer. A data sheet shall be filled out and signed by the manufacturer and the inspector. This data sheet, together with the stamp on the boiler, shall denote that it was constructed in accordance with the A.S.M.E. Boiler Code.

Official Symbol for Stamp to Denote The American Society of Mechanical Engineers Uniform Standard

Each boiler shall be stamped adjacent to the symbol as shown in Fig. 24, Part I, Section I, with the following items, with intervals of about one-half inch between the lines:

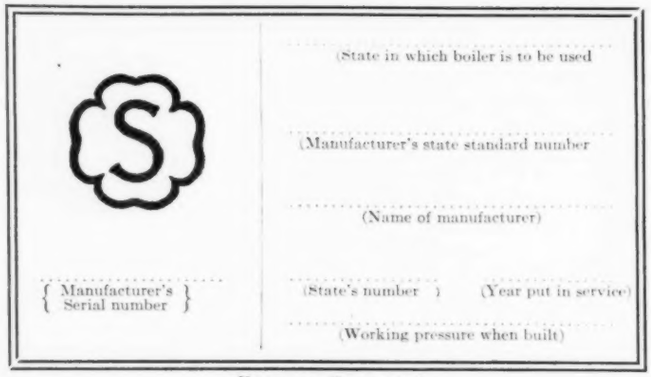
1. Manufacturer's serial number
2. State in which boiler is to be used
3. Manufacturer's State standard number
4. Name of manufacturer
5. State's number
6. Year put in service
7. Working pressure when built.

Items 1, 2, 3, 4 and 7 are to be stamped at the shop where built.

Items 5 and 6 are to be stamped by the proper authority at point of installation.

L-84 (X-333) The stamps shall be located on the boiler head in the cab and should not be covered by lagging and jacketing if the boiler head is lagged.

L-85 (X-334) Each boiler shall be equipped with a metal badge plate, showing the maximum allowable working pressure, which shall be attached to boiler head in the cab. If the boiler head is lagged, the lagging and jacketing shall be cut away a sufficient amount to leave the plate visible.


(State in which boiler is to be used
(Manufacturer's state standard number
(Name of manufacturer)
Manufacturer's Serial number
(State's number)
(Year put in service)
(Working pressure when built)

FORM OF STAMPING

Use of the Boiler Code in Universities

Recognition of the value of the A. S. M. E. Boiler Code as an agency for standardization in this important branch of the industrial field is indicated by its growing use in technical schools and universities as a reference work or textbook. There has been found to be a growing number of engineering departments in the universities of this country which are either utilizing the Code as a reference work, a textbook or as a manual upon which to base their instruction in boiler design.

A. M. Greene, Jr., professor of mechanical engineering, Rensselaer Polytechnic Institute, Troy, N. Y., and member of the Boiler Code Committee, recently canvassed the engineering departments of the various universities and technical schools in order to learn the present status of the Code as an instruction work and the result is of more than usual interest. For the convenience of those having occasion to investigate this matter, the following summary of reports from engineering departments is given.

The following universities use the Boiler Code as a textbook: Massachusetts Institute of Technology, Sheffield Scientific School, Yale University, Armour Institute of Technology (Chicago), Case School of Applied Science (Cleveland), University of Vermont, University of Cincinnati, Johns Hopkins University (Baltimore), University of Michigan, University of Minnesota, and Rensselaer Polytechnic Institute. Rutgers College and University of Texas start with the coming year to make use of the Code as a textbook. The Boiler Code is used as a reference book at the following universities: Vanderbilt University (Tennessee), New Mexico College of Agriculture and Mechanic Arts, Tulane University of Louisiana, University of Colorado, University of Washington, University of Maine, University of Wyoming, Virginia Polytechnic Institute, and Washington University (St. Louis).

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of MECHANICAL ENGINEERING by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

Contributions on Society Policy

MR. CALVIN W. RICE, *Secretary:*

In our efforts to place the organization of The American Society of Mechanical Engineers well abreast of the agencies making for an ever-greater America, we should be unmindful of the lessons of the past if we fail to give special attention to the development of the mechanisms making for free discussion and free speech. Hence it is that the policy which is to control the conduct of the Correspondence Department in MECHANICAL ENGINEERING is by no means without its importance in the whole scheme of A. S. M. E. activities. Should it not be so conducted as to afford one of the principal outlets for comment on, and constructive criticism of, the Society's management and affairs? This is not now its function. In the six issues, January to June of this year, there have been published twelve (12) communications occupying about as many pages and every one of these letters is devoted exclusively to some technical phase of engineering. During the past six months there has not been published a line of "suggestions on Society affairs," which is the kind of contributions which are "particularly welcomed" according to the announcement which stands at the head of the section. This fact is especially significant because during this six months the affairs of the Society have been under special investigation at the hands of the Committee on Aims and Organization.

The late Dr. S. Weir Mitchell, shortly after I was put in charge of Philadelphia's public works, made the suggestion that we should adopt the policy of not only welcoming complaints and constructive criticism but of actively organizing to secure them. He rightly considered such an attitude as fundamental to the building up of our work. Following his advice in the next few months we handled over 100,000 complaints. But with all outlets for criticism thrown wide open and every effort being made by our organization to remedy the causes of criticism, it was not long before the volume of complaints began to recede. The character of the criticisms also became more constructive and we began to receive letters of commendation in increasing number. I am confident that no really great program making for progress can be executed in any field without constantly affording every one at interest a broad opportunity for comment and criticism.

"Formulated rules for the acceptance or rejection" of communications of this character should be very simple. Especially in the beginning I would publish everything offered unless there is an overpowering reason against doing so. At the present time the feeling is quite prevalent that the doors to criticism are not wide open. Until confidence in this matter is fully established the editor is not likely to be overwhelmed with suggestions. As our membership constitutes a carefully selected group the expectation is decidedly against the necessity for the rejection of contributions for cause. In order to fully establish confidence an appeal should be provided where a communication is rejected for cause.

The democratization of the A. S. M. E. will be impossible except as this and other channels for critical comment are thrown wide open. We need to remind ourselves constantly that the cure for democracy is more of it.

MORRIS LLEWELLYN COOKE.

Philadelphia, Pa.

To Mr. Cooke's letter the Secretary has replied as follows:

It is recognized that MECHANICAL ENGINEERING can be improved and developed in various ways and the problem of how best to do that is now being given careful consideration by men with publishing experience and having a thorough acquaintance with the Society's organization and activities.

On account of lack of space and for other reasons which it is not necessary or desirable to specify for the moment, it has been impossible to do immediately all the things that were perceived to be desirable, and a number of them have had to be deferred.

One of these is the further development of the correspondence department in MECHANICAL ENGINEERING which you now advocate. No communications of the character you so wisely sug-

gest have been received, except possibly Mr. Crawford's—with which I assume you are familiar, and my reply to that was in effect that we were already doing what he proposed, but nevertheless, if he would condense his letter we would be glad to publish it. He never came back.

It is hoped that the crowded condition of MECHANICAL ENGINEERING will soon be remedied, as it is generally agreed that it would be very desirable to afford, by means of our journal, a channel of communication between members of the Society; not only upon technical matters, but upon Society affairs as well.

CALVIN W. RICE, *Secretary.*

Fire Engines and the Essentials of Fire Fighting

TO THE EDITOR:

Mr. Fox's paper on Fire Engines and the Essentials of Fire Fighting, presented at the Spring Meeting, covers the general subject in a most complete manner and no particular phase of the many items involved has been given undue prominence to the exclusion of others. However, in order to refresh the minds of those who have dealt with some of the problems in times past and to put on guard those who may be called upon to apply some of the principles without having time to give them proper consideration, it may be desirable to treat certain parts of the subject more in detail.

Although the principles of design of the centrifugal pump and of the gasoline engine are well known by the designers of each class of equipment, yet the observations of the writer during the past ten years show that much trouble is encountered when the centrifugal-pump manufacturer purchases a gasoline engine and attempts to drive his pump with it, or when the manufacturer of a gasoline engine attempts to drive a centrifugal pump with his engine.

The pump manufacturer has tested his pump and determined its most economic speed, capacity and pressure, while the gasoline-engine manufacturer has determined the horsepower delivered at different speeds. In many cases sufficient study is not given to the performance curves of the two pieces of equipment before the capacity and size of each which are to be selected to form the combined motor-driven pump are determined.

In order to have the equipment successful it is fundamentally necessary that the power developed by the gasoline engine at any speed shall exceed that required to operate the centrifugal pump at the same speed. To the casual reader this statement may appear entirely superfluous, yet the failure to meet this axiomatic requirement has cost many manufacturers much time, money and trouble.

The writer is in absolute accord with the statement that the efficacy of fire streams up to 2¼ in. in diameter cannot be materially improved by increasing the nozzle pressure beyond 100 lb. per sq. in. Observations made on a 1½-in. stream by experienced observers showed that the increase in the effective vertical reach when the nozzle pressure was increased beyond 100 lb., was not over 15 ft. up to 150 lb. pressure and that when the nozzle pressure was increased beyond 150 lb. the effective vertical reach decreased. This decrease was evidently due to the increased resistance which the air offered to the surface of the water jet. It is thus evident that a pressure of from 80 to 100 lb. at the nozzle is required to develop efficient streams from deluge sets, turret nozzles, deck guns, ladder pipes and water towers; for hand lines, even when operated by trained men, 60 to 80 lb. is sufficient. There are a few cases, however, when pressures in excess of 100 lb. may be of some advantage on 2-in. and 2¼-in. tips. For instance, in overhauling lumber when stacked, overturning walls or breaking through obstructions when the nozzle can be brought up close, and horizontal or vertical reach are not desired, pressures as high as 200 lb. at the nozzle enable the operator to take advantage of the added momentum of the stream and accomplish more efficient work.

In passing, it may not be out of place to remark that one of the best methods of placing a fire stream in favorable position for observations is to carry them out at night with the stream directed between a bank of electric lights and the observer.

The capacity of a pumper or steamer should always be stated in gallons per minute against the observed net pressure, the latter to be the actual difference in the pressures observed on the suction and discharge sides of the pump. As an example two cases will be cited: (1) An engine is taking suction from a reservoir 5 ft. below the suction inlet and the friction loss through the suction hose when delivering 750 gal. per min. is 6½ ft., making the total lift 11.5 ft. or 5 lb.; the observed discharge pressure is 115 lb., therefore the net head pumped against by the engine is 120 lb. (2) An engine is taking suction from a hydrant fed by a street main carrying a pressure of 55 lb. when the engine is delivering 750 gal.; the friction loss through the hydrant and branch is 3 lb. and through the suction hose 2 lb., making the total friction loss 5 lb., thus delivering a pressure of 50 lb. on the suction side of the pump; the observed discharge pressure is 170 lb., therefore the net pressure pumped against by the engine is 120 lb.

Many engineers of steamers have maintained that their engines worked better at draft than when suction was furnished under pressure from a hydrant. It is the opinion of the writer that this is an erroneous notion and he has never seen it substantiated in practice. At any rate it is an established fact that the pressure furnished on the suction side of the pump increases the capacity of a pumper when delivering at pressures above that pressure at which it is rated.

If a pumper is rated at 750 gal. at 120 lb. net pressure and water is delivered to the suction side of the pump at 0 lb. pressure, then it will discharge somewhat more than one-half this quantity at 200 lb. pressure and a little more than one-third the quantity at 250 lb. pressure. Now if water is delivered to the suction side of the pump under 80 lb. pressure the discharge pressure will be 200 lb. and the capacity will remain at 750 gal., and if the water is delivered to the suction under 130 lb. pressure the pump will continue to discharge 750 gal. per min. with a discharge pressure of 250 lb.

It is thus evident that the pressure in the water mains should be taken advantage of in all cases. This is particularly important in large fires where high pressures are required to develop the more powerful streams and to overcome the friction losses in long lines of fire hose which must be laid from the engines located farthest from the fire. Where good hydrant pressures are available, say from 40 to 60 lb., the more nearly can the rated capacities of the engines be maintained when required to work against discharge pressures greater than 120 lb.

The one and main object of the pumper or steamer is to deliver water at the nozzle at a pressure suitable to develop an efficient fire stream. Now it has been shown that any increase in discharge pressure reduced the delivery of the apparatus, therefore every means should be adopted which will relieve the necessity of raising the discharge pressure. Increasing the carrying capacity of the hose lines from the engine to the nozzle will cut down the friction loss which in turn will cut down the pressure at the engine which is required to deliver the water at the nozzle under suitable pressure.

The use of 3-in. hose will accomplish this result in the most economical manner and practically the same results can be accomplished by siamesing 2½-in. hose lines. For a given quantity of water flowing the friction loss through a 3-in. hose line is about one-third that through a 2½-in. line of equal length. Two 2½-in. lines siamesed offer about one-fourth the frictional resistance of a single 2½-in. line. It therefore is advisable to lay 3-in. hose lines from pumpers to the entrance of buildings and to ladder pipes, turret nozzles, deluge sets and water towers in order to enable the pumper to deliver larger quantities of water.

The successful fighting of a fire depends much upon the development of powerful hose streams and these in turn depend upon the efficient operation of the pumpers or steamers. An untrained and unexperienced engineer may so operate an engine that is in first-class condition that it will not give as good service as a much poorer engine is well-trained hands. So much depends upon the operation of pumpers and steamers that it is of prime

importance that the crews be trained in the operation of their machines at capacity at frequent intervals, say, once a month.

CLARENCE GOLDSMITH.

New York, N. Y.

Comment on the Still Engine

TO THE EDITOR:

Roughly, an internal-combustion engine converts a third of its heat supply into power and throws away another third in the jacket discharge and a final third in the exhaust. The Still engine represents an attempt to reclaim the wasted two-thirds by means of a steam plant. The steam-plant efficiency can scarcely exceed 20 per cent. Hence the maximum potential efficiency from the apparatus proposed is $\frac{1}{3} + (0.2 \times \frac{2}{3}) = 46.7$ per cent.

The exhaust-gas heat has the desirably high temperature. Transmission from dry gas is slow and transmitting apparatus may be (as with hot-air engines) hard to maintain, but experience with economizers has shown these objections not to be fatal. A transmitting surface of 3 sq. ft. per hp. of the internal-combustion cylinder should be sufficient.

The jacket heat exists at low temperature and hence at low availability. The proposed engine increases the temperature and further increases availability by using the exhaust gas. The jacket heat (except for radiation) is all reclaimed. The exhaust heat is reclaimed to the extent represented by a temperature drop from 900 deg. to 150 deg. Unfortunately, 80 per cent of these reclaimed amounts must immediately be thrown away to the steam-plant circulating water.

A steam generation of 7 lb. per b.hp-hr. can scarcely be expected. Under the illustrated conditions, this implies a jacket loss of about 6300 B.t.u. per hr., or $2\frac{1}{2}$ times the normal.

The general idea is sound, but it makes the further extended development of the gas engine contingent on some radical improvement in the economy of the steam engine.

W. D. ENNIS.

New York, N. Y.

The First Steamship to Cross the Atlantic

TO THE EDITOR:

In the June number of MECHANICAL ENGINEERING, on page 554, there is an article entitled The Crossing, which states than "On May 26, 1819, an American ship, the *Savannah*, was the first steam-driven vessel to cross the ocean, etc."

As a matter of history the *Savannah* did not make the entire voyage under steam. As stated in the Encyclopedia Britannica, "She was fitted with sails, and used them in rough weather, unshipping her paddle boxes."

I give below extracts from the Toronto *Daily Star* treating on this very matter which I think should be put before the Society.

A letter recently appeared in the London *Times* from Prof. W. H. Vander Smissen, of the University of Toronto, now resident in England, in which he pointed out that it was neither the American-owned *Savannah* nor the British steamship *Sirius* or *Great Western*, but the Canadian-owned and built *Royal William* which was the first vessel propelled by steam to cross the Atlantic.

From time to time disputes have arisen on this question, and Professor Vander Smissen recalls that in 1894 the Earl of Aberdeen, as Governor-General at the time the Intercolonial Conference was in Ottawa, unveiled a tablet placed on the wall of one of the corridors of the Parliament Buildings inscribed with the details of the *Royal William's* performance. The burning of the buildings early in the war destroyed this tablet, which it is hoped will be replaced. Professor Vander Smissen says that the *Royal William* was designed by Mr. James Goudie, a native of Quebec. Her builders were Messrs. Campbell and Black, of that city; she was engined in Montreal, and before making her memorable trip from Quebec via Pictou, N. S., to London, in August, 1838, had traded between Quebec, Halifax, and Boston. She was bought by the Portuguese Government and renamed, and later served as a Spanish warship under the name *Isabel Segunda*. She had a length of 176 ft., a width between the paddle boxes of 28 ft., and a gross tonnage of 1,370.—*Toronto Daily Star*, May 7, 1919.

It was in 1833 (not 1838, as previously stated) that the *Royal William* made her famous voyage, and she was not only the first ship to cross the Atlantic under steam, but the first to be built with a system of water-tight compartments and the first war steamer that ever fired a shot. This was in 1836, after she had been sold to the Spanish Government and was being used (under the name *Isabel Segunda*) in operations against Don Carlos

The origin of the Canadian steamer which thus has a triple distinction in marine history is rather interesting. Influential men who in 1821-24 wished to bring about a union of the North-American Provinces were met with the objection that there was really no inter-Provincial trade. As a result of the discussion subsidies were offered by the Legislatures of Lower Canada and Nova Scotia for steamship communication between Quebec and Halifax. Citizens of the two cities formed a joint stock company, and the *Royal William* was built in 1830-31 at Quebec at a cost of about $80,000. She was fitted with 200 hp. engines at Montreal, and in August of 1831 steamed from Quebec to Halifax with 90 passengers, 120 tons of coal, and some other freight. In 1833, after being sold to satisfy a mortgage, she left Quebec for London, Eng., via Pictou. The voyage from the latter port to Gravesend lasted from August 18 to September 11, and steam was utilized the entire distance.—*Toronto Daily Star*, June 14, 1919.

To this it may now be added that two Britishers on June 15, 1919, made the first trip from Newfoundland to Ireland successfully by aeroplane.

JAMES MILNE.

Toronto, Ont.

James Watt Centenary

On August 25 one hundred years will have elapsed since the close of James Watt's life.

In honor of this centenary the engineers of Birmingham, England, the city of Watt's adoption, where his most important work was accomplished, are to provide permanent memorials. These are to consist of (1), the endowment of a professorship of engineering to be known as the James Watt Chair at the University of Birmingham, for the promotion of research in the fundamental principles underlying the production of power and the study of the conservation of the natural sources of energy; (2) the erection of a James Watt memorial building which shall serve both as a museum for examples of the work of Watt and his contemporaries, and as a meeting place and library for scientific and technical societies; and (3) the publication of a memorial volume.

Inasmuch as the benefits which the genius of James Watt bestowed on mankind are too widespread for any purely local celebration, the exercises in connection with the establishment of the memorials will be of an international character, with representatives from various organizations in different countries.

The representative of The American Society of Mechanical Engineers will be Mr. W. E. Symons, Chairman of the Finance Committee of the Society, who is now on his way abroad. A further announcement will probably be made in a later issue.

In his work throughout the country in behalf of discharged service men Colonel Arthur Woods, Assistant to the Secretary of War in charge of finding employment for demobilized soldiers, sailors and marines, has learned that in many sections people generally do not know just what the Government is doing to enable men disabled in the line of duty to reëstablish themselves in civil life. The authorized agency of the Government for carrying on this work is the Federal Board for Vocational Education, which is charged by Congress with the "vocational training of disabled soldiers and the placement of rehabilitated persons in suitable and gainful occupations," after their discharge from the Army.

Disabled men should accordingly get in touch with this Board which will place them in educational institutions, where suitable trades or occupations will be taught them according to their individual experience, capacities and preferences. A disabled man so incapacitated that he cannot take up his old occupation will be allowed to choose any occupation or trade which he thinks he would like to follow, subject, of course, to approval by the Board, which is interested only to be assured that the man is fitted to pursue the occupation or trade elected.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A. S. M. E.

Coöperation in Research by Government of Great Britain

THE following letter indicates action of the British Government in aiding research and is given for the information of the membership of the Society:

EDITOR MECHANICAL ENGINEERING,
29 West 39th Street, New York.

Dear Sir:

The action of the British Government, which has placed a fund of £1,000,000 at the disposal of the Research Department to enable it to subsidize industrial research, should be of interest to mechanical engineers and manufacturers.

The opinion is held in some quarters that we have been ahead of Great Britain in the matter of research work. The work of our Agricultural Department, Bureau of Mines and Bureau of Standards are held up as models of Government Research, and the work of the Altoona Locomotive Testing Plant of the Pennsylvania R.R., the Nela Park Laboratories of the General Electric Company and the laboratories of the Eastern Kodak Company, to select a few examples which occur to me, are held up as models of research work by private industrial companies.

The British system looks to the coöperation of Government and private effort. Thus, to select an example, instead of our Bureau of Mines making a more or less independent study of the combustion of coal in various types of furnaces and on various types of grates or stokers, the British idea is that such work should be done by an association composed of grate and stoker manufacturers aided financially by the Government. Each firm contributes a certain amount of money to its association and naturally has a voice in determining the problems to be studied. The Government supplies a certain aid or subsidy to the association, also exemption from taxation on funds contributed by individual companies.

At first it may seem that such an arrangement would be superior to our own because the work undertaken would conform more nearly to the immediate and pressing needs of the manufacturers. But, viewing the problem in its broad aspect and from the standpoint of future wealth and prosperity of the nation, it does not necessarily follow that all research work should be intensely commercial, that is, directly trained upon a pressing commercial problem. Many of the most valuable scientific discoveries have been made by men who were working purely in the search for truth and without any definite commercial object.

Our great national research organizations might therefore confine their efforts to work which has a less definite commercial value, while the more pressing problems could be handled by research associations after the British pattern and also, of course, by individual research work in each plant. This would make three links in the chain of research work. The work of the various research bodies could be coördinated or harmonized by suitable councils. Such bodies would recognize problems of a more purely scientific nature to be undertaken by the national bodies which have grown out of and are suggested by the more pressing commercial problems being studied by the research associations, or, on the other hand, recommend problems for study by the associations which have grown out of more general investigations made by the national organizations. To return to the example of the combustion of coal: elaborate studies of how coal is burned on grates and stokers are bound to suggest ideas for the design of a better stoker. Such a problem cannot be investigated further, however, by a purely government body, because it involves invention and patent rights. The British idea is to have such work done by a coöperative association of manufacturers and any patent rights become the property of the association, subject only to a few limitations, such as approval of foreign license. If the Government controlled inventions an undesirable, not to say dangerous, clash between industry and Government might eventually arise.

I am attaching the draft letter concerning the conditions as to the payment to research associations by the British Government.

Very truly yours,
(*Signed*) PAUL BANCEL.

New York, May 12, 1919.

Labor and Scientific Research

The American Federation of Labor at its Atlantic City meeting adopted a series of resolutions advocating scientific research as the basis for increased productivity in the industries and the promotion of the health and well being of employees. These resolutions, the most important of which were printed on page 625 of MECHANICAL ENGINEERING for July, call attention to the numerous pressing problems whose wise solution depends upon scientific and technical research, and to the overwhelming importance of science and technology to the national welfare whether in war or peace.

A—RESEARCH RESULTS

Cement and Other Building Materials A3-19 Roofing Materials, Specifications for plastic cements having troweling and brushing consistency for coal tar, pitch and asphalt from experiments. Address Director, Bureau of Standards, Washington, D. C.

Cement and Other Building Materials A4-19 Effects of Fine Grinding of Portland Cement. Cement ground 99 per cent fine when used in concrete mixtures of varying proportion at age of 7 days gave increase of strength ranging from 15 to 61 per cent of concrete of normal fineness. Tests of 28 days 3 months, 6 months and one year are in progress. Address Director, Bureau of Standards, Washington, D. C.

Cement and Other Building Materials A5-19 Reinforced-Concrete Beams. Recent tests of beams failing by compression on upper side indicate that ultimate compressive strength of concrete is considerably greater when tested in form of beam than when tested in the form of prism under uniformly distributed load. This fact gives promise of forming a reliable basis for increase in safe working stress in compression. Work is now being carried on regarding shearing stresses in beams. The work was conducted in connection with the design of reinforced-concrete ships. Results indicate that much larger web reinforcement may be more advantageously used than that hitherto deemed permissible. Address Director, Bureau of Standards, Washington, D. C.

Heat A1-19 Heat-Transfer Rate in Boiler Tests. Experiments on the rate of heat transfer from a hot gas through a cooler metallic substance. Babcock & Wilcox Company, 1916. The results of these experiments are given in a book of 84 pages published by the Babcock & Wilcox Company, New York. The heat-transfer rate in B. t. u. per hour per deg. fahr. temperature difference per sq. ft. is given by the formula

$$R = a + b\,(W/A)$$

where W = weight of gas passing through absorbing surface per hour, in lb.

A = area of cross-section through which gas passes, sq. ft.

The value of a is 2.0; b is 0.0014 in general, although it changes with temperature as shown by Figs. 1 and 2.

The temperature difference to be used is given by

$$\text{Temp. Diff.} = \frac{\triangle T_1 - \triangle T_2}{\log_e (\triangle T_1 / \triangle T_2)}$$

where $\triangle T_1$ and $\triangle T_2$ are temperature differences between gas and steam at entrance and exit. Figs. 1 and 2 show the plotted results for values of R with ordinary tubes and for annular channels.

Electric Power A2-19 The Present Development of Transmission Lines in Kansas, by F. Ellis Johnson, University Experiment Station, University of Kansas, Lawrence, Kan. Address Director A. A. Potter. This Bulletin describes the growth of transmission lines, their origin, agreements, service to farmers, popular feeling, industrial power lines, agricultural lines, construction features and economy.

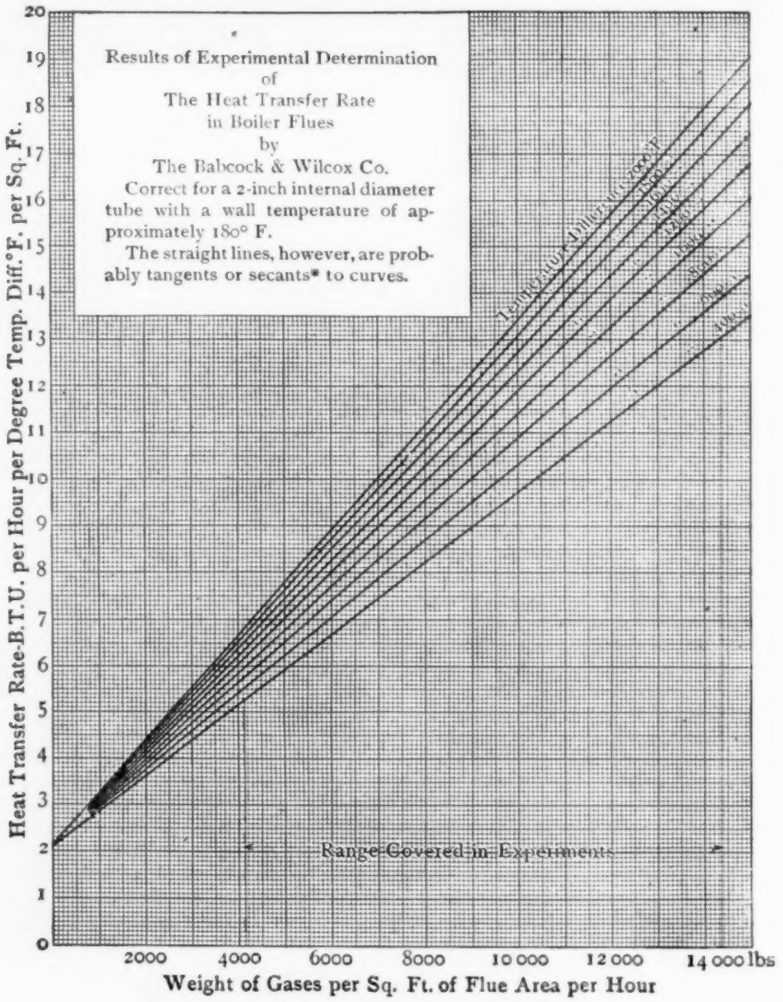


FIG. 1 HEAT-TRANSFER RATES FOR 2-IN. BOILER TUBE

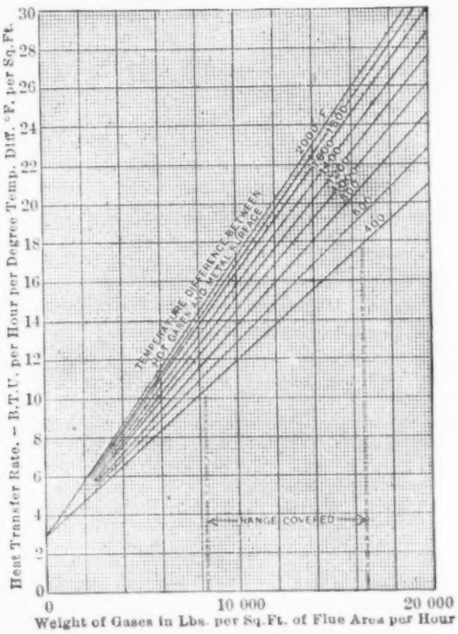

Heat Transfer Rate, — B.T.U. per Hour per Degree Temp. Diff. °F. per Sq. Ft.
Temperature Difference between Gases and Metal °F.
RANGE COVERED
Weight of Gases in Lbs. per Sq. Ft. of Flue Area per Hour
0
10 000
20 000

FIG. 2 HEAT-TRANSFER RATES FOR TUBE 2 IN. IN INTERNAL DIAMETER FITTED WITH A CORE 1 IN. IN EXTERNAL DIAMETER

Leather and Glue A1-19 Linoleum Cements. Investigation on linoleum cement showing that shellac cements with alcohol as thinner with and without finely powdered mineral filler were more waterproof and held linoleum more tenaciously to concrete or steel than those cements made from dextrin or other water-soluble gums or some other resins cut in alcohol. Shellac cement with mineral filler adhered more tenaciously and did not become brittle or dry as that without filler. When water-soluble pastes are used a strip 1 ft. on either side of seam should be cemented with waterproof cement. Address Director, Bureau of Standards, Washington, D. C.

Metallurgy and Metallography A4-19 The Relation of the Phase Changes to Microstructure in the Heat Treatment of Aluminum Bronze, by L. R. Seidell and G. T. Horvitz. See *Chemical and Metallurgical Engineering*, or address New York Testing Laboratory, 51 E. 42nd St., New York.

Metallurgy and Metallography A5-19 The Relation of Quenching Temperature to the Microstructure in High-Speed Steel with Effect on Physical Properties. Paper to be read before American Steel Treaters' Society. Address New York Testing Laboratory, 51 E. 42nd St., New York.

B—RESEARCH IN PROGRESS

Apparatus and Instruments B7-19 Diaphragm Indicator for Internal-Combustion Engines. Development work is being carried on by the Bureau of Standards on an indicator for gas engines at high rotational speed with a diaphragm indicator with beam of light. Address Director, Bureau of Standards, Washington, D. C.

Apparatus and Instruments B8-19 Bourdon Gages for 30,000 lb. per sq. in. A study of the performance of two Bourdon pressure gages for 30,000 lb. per sq. in. with reference to drift of indication.

Apparatus and Instruments B9-19 Abrasion Machines. Investigation to determine relationship, if any, which exists between abrasion test on Deval machine when using shot and when no shot are used. By R. A. Seaton, Engineering Experiment Station, Kansas State Agricultural College, Manhattan, Kan.

Cement and Other Building Materials B4-19 Reinforced-Concrete Beams. Recent tests of beams failing by compression on upper side indicate that ultimate compressive strength of concrete is considerably greater when tested in form of beam than when tested in the form of prism under uniformly distributed load. This fact gives promise of forming a reliable basis for increase in safe working stress in compression. Work is now being carried on regarding shearing stresses in beams. The work was conducted in connection with the design of reinforced-concrete ships. Results indicate that much larger web reinforcement may be advantageously used than that hitherto deemed permissible. Address Director, Bureau of Standards, Washington, D. C.

Cement and Other Building Materials B5-19 Reinforced-Gypsum Beams. Standards of design for beams and floors with gypsum in connection with Committee C 11 of the American Society for Testing Materials. Bureau of Standards. Address Director, Bureau of Standards, Washington, D. C.

Cement and Other Building Materials B6-19 Run-of-Pit Gravel for Concrete Without Use of Other Aggregate in Kansas. Engineering Experiment Station, Kansas State Agricultural College. Address Dean A. A. Potter, Manhattan, Kan.

Cement and Other Building Materials B7-19 Sand-Cement Concrete Without Coarse Aggregate. A research to determine at what price crushed stone can be used. A study for localities where little coarse aggregate is available. Engineering Experiment Station, Kansas State Agricultural College. Address Dean A. A. Potter, Manhattan, Kan.

Cement and Other Building Materials B8-19 Use of Joplin Chats as Concrete Aggregate in Coarse or Fine Condition. Engineering Experiment Station, Kansas State Agricultural College. Address Dean A. A. Potter, Manhattan, Kan.

C—Research Problems

Glass and Ceramics C1-19 Enameling by the Use of Colloids instead of Petroleum Solvents. General Efficiency Department, Chevrolet Motor Company, Tarrytown, N. Y.

D—Research Equipment

Aircraft D2-19 Propeller Dynamometer. Designed for 14 lb-ft. torque, 60 lb. thrust and 5600 r.p.m. to test model air propellers in large wind tunnel through variable-speed motor of 15 hp. capacity. Address Commander McEntee, Navy Yard, Washington, D. C.

Aircraft D3-19 Research Facilities at the Curtiss Engineering Corporation. The Curtiss Engineering Corporation is situated conveniently near New York City, the aviation fields and the bays of Long Island, at Garden City, L. I. The plant is primarily an experimental plant and is devoted to aeronautical research in all forms. Address Research Laboratory, Curtiss Engineering Corporation, Garden City, L. I. (See Research Personal Notes. *Aircraft E1-19*, for private use of this laboratory.)

Equipment. The plant with all manufacturing facilities.

Research Department. This department has three wind tunnels in operation:

One large Eiffel-type wind tunnel recently completed, run by a 400-hp. gasoline motor, electrically controlled. The experimental chamber is an improvement on all existing types. The experimental chamber is 15 ft. long, 13 ft. wide, and about 20 ft. high, and the cross-section of the air stream at the balance is 7 ft. Speeds up to 100 m.p.h. are now obtainable and shortly will exceed this value. The balance is a specially designed one of the unipivot type sensitive to less than 0.0001 lb. of wind force.

One 4-ft. wind tunnel of the enclosed type improved, actuated by a Curtiss OX motor and an especially designed air-turbine propeller; a special Curtiss-type wind-tunnel balance is used. Air speeds up to about 80 m.p.h. are available in this tunnel.

One 2-ft. wind tunnel for qualitative work, run by an electric motor giving wind speeds around 30 m.p.h.

A completely equipped model-making and instrument-making shop. This shop is equipped with three lathes (one of great precision and all electrically driven), one jointer, one hand saw and a wood-turning lathe, and a number of special apparatuses to facilitate the work of model making.

Research Work. The Research Department undertakes any special investigation of a theoretical nature required. Wind-tunnel tests of all kinds are carried out in these tunnels by a competent staff. Tests on new wing sections at various speeds, tests on new models giving stability and performance before the full-size machine is built or flown make for the utmost safety in the work. Tests on stream-line forms such as fuselages, dirigible shapes, flags, propellers, gasoline pumps, generator turbines, etc., are being made continually.

The Curtiss Aeronautical Library is a very complete collection of aeronautic literature in all languages. It subscribes to all aeronautic periodicals of any importance.

Chemical and Materials and Heat-Treatment Laboratories. These laboratories are equipped to test all materials entering into airplane construction.

Staff of Research Department. J. P. Tarbox, Director, Dr. J. G. Coffin, Assistant Director and Physicist, and three to five technical research engineers and a librarian. The model shop employs a corps of expert model makers.

Staff of Chemical and Material Laboratories. Mr. Frisbie, Mr. Crossley, Chemist.

Research Time. All of the work in general is of a research nature. About one-half is devoted to pure research.

Automotive Vehicles and Equipment D1-19 Equipment, Personnel and Problems of the Packard Engineering Laboratory. Address Packard Motor Car Co., Engineering Executive, Detroit, Mich.

Equipment. The equipment is divided into two classes, motor-testing equipment and bench-testing equipment. The motor-testing equipment consists of three electric cradle-type dynamometers, one for high-speed passenger-car work up to about 100 hp. and 3500 r.p.m., an airplane-engine dynamometer capable of carrying 400 hp. continuously and over 500 hp. for a brief period for speeds up to 2000 and 2200 r.p.m. maximum, and a truck-engine dynamometer to take care of heavy torques at low speed and capable of carrying about 60 hp. at 1000 r.p.m. The accessories of these three dynamometers are practically identical. The grids of the absorption resistance are located in a separate room and the heat is carried away by forced draft.

In laying out the dynamometer room proper the chief point was to eliminate all possible obstructions above ground in the way of piping and wiring in order to preserve a clean room free from excessively high temperatures or noxious gases so that the operators would have the best of surroundings and be able to concentrate on the problems at hand. This layout permitted of a maximum amount of daylight, which is very desirable for accurate work. The exhaust system is taken care of by underground tunnels connected to a 10-hp. electric fan located outside of the room and communicating with a stack extending above the roof. Communication between the engine exhaust pipe and the exhaust tunnel is afforded by a standard manhole cover into which suitable lengths of flexible steel tubing are screwed for connection to the exhaust pipe of the engine. For airplane-engine work exhaust stacks are used which discharge into suitable sheet-iron exhaust boxes which take the place of the manhole cover so as to present a minimum obstruction to the free exit of the exhaust gases.

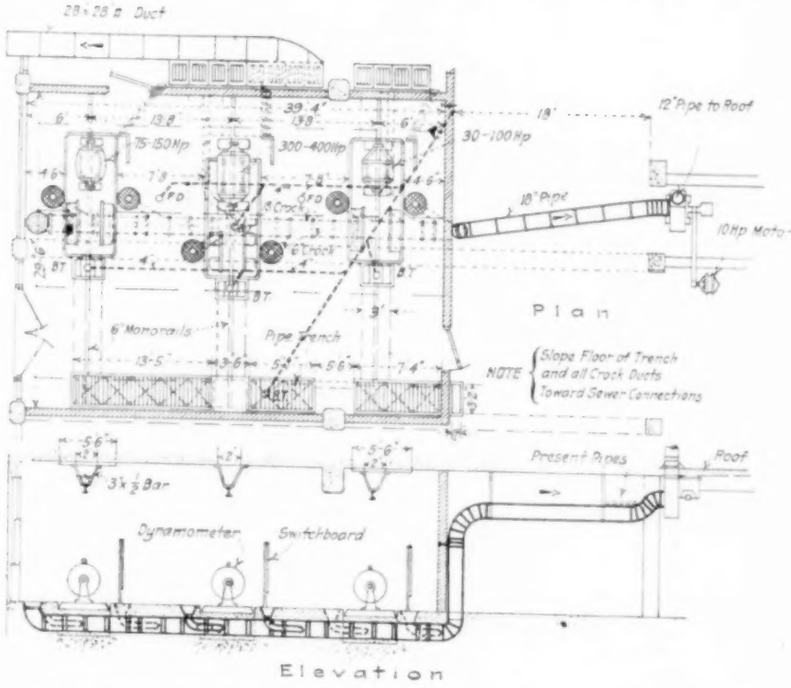


Fig. 3 Plan and Elevation of Packard Laboratories for Heavy Motors

Gasoline is delivered to the dynamometer room by the remote-control Bowser system with a meter located in the dynamometer room. Two gasoline tanks are provided at an elevation of about 8 ft. from the floor, one of which is mounted stationary and the other is fixed on the platform of a sensitive balance. Gasoline feed pipes to the three dynamometers are run in roomy tunnels under the floor, and by a system of six valves it is possible to feed any one of the three dynamometers from either the fixed tank for ordinary runs or from the tank mounted on the scales for economy tests.

Water piping and the water system are underground as far as possible, a 25-gal. tank being located in each of the three tunnels leading to the respective dynamometers. Suitable hot- and cold-water connections are made to this tank and controlled by valves the handles of which project above the floor. Access to these tunnels is provided by hatchways which are readily removable. The entire piping and tunnel layout is clearly shown in Fig. 3.

Ample bench room is provided to do the minor fitting work required in work of this character. Dynamometer readings consist of speed

and torque readings. Speed readings are taken by carefully calibrated tachometers and checked by positive counters. Torque readings are taken by means of springless scales and checked by tare beam. Specially designed dynamometer couplings are used to take care of slight misalignments. A uniform system of engine controls is mounted on each dynamometer so as to be readily adaptable to any kind of engine. A trolley runs over each dynamometer and a chain hoist is used for mounting and dismounting the engines. The airplane dynamometer has in addition to its gasoline and water feeds an oil-circulating feed, the oil being returned to a tank mounted on a sensitive scale adjacent to the gasoline scale. Oil consumption of truck and car motors is arrived at by separate portable apparatus which involves the use of a small oil pump driven by an electric motor and an oil reservoir mounted on a sensitive scale. The engine being tested with latter apparatus is run with a dry sump. See Fig. 4.

Compressed air, suitable sockets for electric drills, hot and cold water, 6-volt battery current, etc., are all piped to the front of each dynamometer for purposes required in various tests.

The bench-dynamometer room (Fig. 5) is intended for all tests other than motor-power tests and its equipment is of growing and varied nature. It is not necessary to describe in detail each piece of apparatus but the diversity of tests can be judged by the following list:

1 Endurance tests on plain and ball bearings.

2 Endurance tests of magnetos, generators, starting motors, fans, oil pumps, air pumps, tire pumps, camshaft drives, universal joints, and many other accessories which are submitted from time to time. In this connection the object is to provide in each case a more or less permanent set-up so as to be available for a repetition of the test at any time in the future.

3 Calibration of radiators to determine their efficiency alone and in conjunction with various water pumps and fans.

4 Storage-battery characteristics.

It can be readily realized that the above list does not by any means comprise all the various experiments which come under the general heading of bench tests. It is also impossible to start out with a laboratory for this work fully equipped since the very nature of the work demands the designing of new equipment from time to time. A comprehensive switchboard for electric-motor speed control has been worked out for all the motors used in this room and some such system is essential to do accurate work of this nature. In general each piece of apparatus is directly connected to an electric motor and in no case is a belt or any other form of a friction drive used. Direct current (220 volts) is used and the field and armature connections from each motor are brought to a common switchboard. A bank of cast-iron grids is connected across the line and 220 equally spaced taps off of these grids are connected to a special dial switch. By means of suitable plugs similar to a telephone switchboard any motor in the room can be connected to this dial switch and in this manner its speed variation can be controlled very closely since the increments of voltage supplied to the armature or field differ by only one volt. When the proper speed has been reached for any particular run the proper plug connection is made and the dial switch is again free to use with any other motor.

Another room is provided into which cars and trucks can be run for such special work or inspection as may be desired.

Personnel. The dynamometer-room personnel consists of a foreman with about twelve men with particular experience for this class of work. This demands a thorough understanding of all engines and a fair amount of mechanical skill of a wide nature. The office force consists of four engineers and a man to take care of the clerical and stenographic work. The work is generally divided among the engineers in a manner to develop specialists. One man, for example, will concentrate on the getting out of reports, another man will supervise bench tests, another man will do the necessary designing of all the apparatus required and concentrate on calculations, etc. A cast-iron rule is that a record be kept of every experiment whether successful or not.

Problems. The problems presented generally can be classed as follows:

1 Routine Work. This is generally a matter of proving out certain elements in a new design and for the most part present no difficulties since it is generally a comparison between an old design and a new one. These tests, of course, cover a very wide range, some might take but a few minutes and others might stand over a period of several months.

2 Factory Troubles. All tests pertaining to factory troubles are given precedence over all other work and these generally consist of troubles which do not manifest themselves until wholesale production of a certain design is gone into. Work of this character demands the utmost concentration and all possible speed.

3 Research Work. This work generally contemplates improvements in the product which are not essential for immediate production and which are of such a character as not to permit of their solution on the drawing board. This work is used as a filler-in proposition and generally jobs coming under the previous headings have precedence over this work. A certain amount of design work is necessary to carry on these researches and this necessitates the cooperation of the other Engineering Department.

No work is undertaken by this Department unless the Engineering Executive gives his authority and reports are given him from time to time showing the progress made on various tests. In case of a conflict as to the precedence of various tests, appeal is made to the Engineering Executive. This department also controls all road testing and aims to have on the road a car or truck for day and night running at all times. These cars operate over carefully-laid-out routes with competent crews for operation. Careful reports are kept of all incidents affecting the tests.

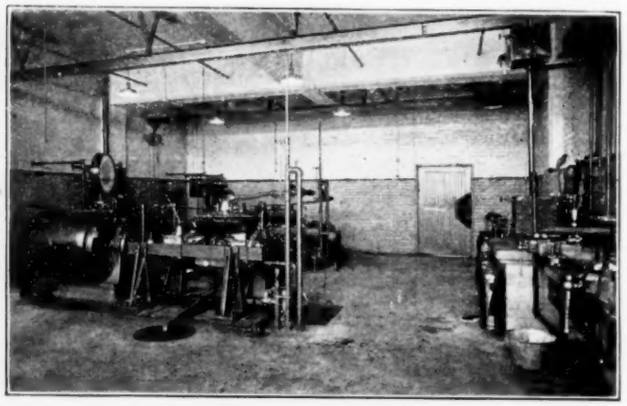


FIG. 4 PACKARD LABORATORY FOR HEAVY MOTORS

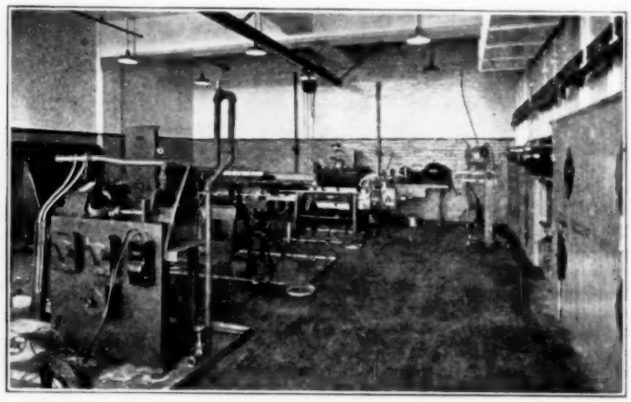


FIG. 5 PACKARD LABORATORY FOR SMALL DYNAMOMETERS

In general it is the aim of this department to insure that all defects in apparatus undergoing tests should be brought to light and viewed from this light its responsibilities are great. The vast amount of money spent by all automobile concerns in service and free replacements can be greatly diminished by the use of suitable testing equipment and it is felt that this aspect is being realized more all the time. The fact that so many points in design can be definitely proven to be good or bad by accelerated test is of the utmost importance in proving out a design. An engine for instance can be run for 24 hours a day at a speed of 60 miles per hour on the dynamometer and in this manner an astonishingly high mileage can be secured in a very short time. Of course, good judgment must be exercised in making these tests since under certain conditions they can be very much more severe than will ever be encountered in service, but in general the only disadvantage from going by an accelerated test is that the factor of safety may be too high and the particular part may be too heavy or too expensive.

Curtiss Engineering Corporation D1-19 Description of equipment and personnel under *Aircraft D3-19*.

Detroit Testing Laboratory D1-19 Chemical and physical apparatus, testing machines for strength, hardness, impact, metallographic equipment. High-temperature furnaces and pyrometers for heat treatment of metals, chemical processes and oil production from shale.

The James H. Herron Co. D1-19 Laboratories equipped for chemical analysis, physical tests, metallurgical and metallographic work, 500,000-lb. universal machine, 200,000 lb. compression machine, Brinell hardness tester, Shore hardness tester, metallographic equipment for ferrous and nonferrous metals, crucible, open-hearth and electric furnaces;

heat-treatment apparatus. The laboratory works in iron, steel, bronzes, brass, bearing metals, clays, refractories, enamels, fuels, oils and lubricants. The work of research for development is one feature of the laboratory. Address James H. Herron Co., Cleveland, Ohio.

Robert W. Hunt Company D1-19 Laboratory for commercial testing for clients. Address Robert W. Hunt Co., Chicago, Ill. The general equipment of the physical testing laboratory is as follows:

Riehlé horizontal testing machine fitted with 200-lb. and 1000-lb. spring balances
Riehlé vertical-screw machine, 50,000 lb. capacity. Maximum sizes taken: 6 ft. on tension tests, 20 in. on compression tests, and 16 in. on transverse tests
Riehlé vertical-screw machine, 30,000 lb. capacity. Maximum sizes taken: 5 ft. on tension or compression tests, 8 ft. on transverse
Riehlé vibratory machine for staybolt iron
Standard brick rattler
Standard Deval abrasion machine
Bausch & Lomb microphotographic outfit
Gas furnace and LeChatelier pyrometer
Shore scleroscope
Standard Tyler sand sieves
Stone sieves, size 2 in.—¼ in.
Completely equipped chemical laboratory. Rotary cement kiln, ceramic furnace for shales and clays, and apparatus for melting points to 3000 deg. fahr.

Kansas State Agricultural College, D1-19 Equipment for Research.

Material-Testing Machines
50,000-lb. Riehlé universal testing machine
100,000-lb. Riehlé universal testing machine
200,000-lb. Olsen universal testing machine adapted to beams to 20 ft. span and columns of 15 ft. high
250,000-lb. torsion testing machine
Upton-Lewis toughness-testing machine for reversal of stress
Shore scleroscope for hardness
Brinell hardness machine
Bausch & Lomb metallurgical microscope

Laboratories
Cement laboratory
Concrete and aggregate laboratory
Road-materials laboratories for non-bituminous and bituminous materials
Hydraulic laboratory with weirs, orifices, tanks, pumps, rams, turbines, meters, pipes and fittings.

Lincoln, Hanson & Abbott D1-19 Laboratories of Lincoln, Hanson & Abbott, Portland, Me., equipped for standardizing instruments, testing transmission systems and central stations, investigations of high voltage, and with apparatus for making tests of materials for underwriter's requirements. Laboratories also equipped for photometric measurements. The equipment is complete for all kinds of electrical investigations.

Marine Engineering D1-19 Ship Model Basin. Experimental model basin, Navy Yard, Washington, D. C., 380 ft. long, 40 ft. wide and 14 ft. deep with tow carriage carrying resistance dynamometer and other measuring apparatus. Capacity of dynamometer, 450 lb. maximum. Speed of carriage, 18 knots (or 30 ft. per sec.). Basin is equipped for measuring rolling and pitching. For shallow-water experiments false floor can be installed. Apparatus for producing waves in basin is installed. Propellers of 16 in. in diameter or 6 in. in diameter may be tested at this plant. Address Commanding Officer, Department of Construction and Repair, Navy Yard, Washington, D. C. See RESEARCH PERSONNEL NOTES, *Marine Engineering, E1-19*, p. 537 of June issue, for use of above in interest of private parties.

Metallurgy and Metallography D3-19 Electric Furnaces. Northrup Ajax furnace operated with alternating current of from 10,000 cycles per second, giving temperature within an inductor coil of 2500 to 2800 deg. cent. Furnace of special value in obtaining carbon-free melts. Address Pyrolectric Instrument Co., Trenton, N. J.

Packard Motor Car Company D1-19 Research Laboratory. See *Automotive Vehicles and Equipment D1-19.*

New York Testing Laboratory D1-19 Organization composed of graduate chemists and metallurgists with wide experience in the manufacture of iron and steel, furnaces, foundry practices for ferrous and non-ferrous metals, forging practices, heat treatment, physical tests, impact, metallographs, analyses. Address New York Testing Laboratory, 51 E. 42nd St., New York.

Henry S. Spackman D1-19 Private Laboratories of Henry S. Spackman Engineering Company, 2024 Arch St., Philadelphia, Pa. Specially equipped for chemical and physical tests of cement, concrete, steel, iron and alloys.

Enrique Touceda D1-19 Laboratory of Enrique Touceda, Albany, N. Y. Laboratory well equipped for physical and chemical properties of ferrous and non-ferrous metals and alloys. Structural composition and heat treatment. Laboratory well equipped for special research. Analytical investigations of a routine nature are made. Address Enrique Touceda, Albany, N. Y.

E—RESEARCH PERSONAL NOTES

Aircraft E1-19 Use of Research Laboratory of Curtiss Engineering Corporation.

The equipment of this laboratory may be used for solutions and investigations of problems in aerodynamics at reasonable rates. Address Curtiss Engineering Corporation, Garden City, N. Y.

F—BIBLIOGRAPHIES

Air F2-19 Utilization of Wind Power. A bibliography of 9 pages. Search 2430. Address A. S. M. E., 29 West 39th St., New York.

Apparatus and Instruments F1-19 Wet Gas Meters. A bibliography of 1½ pages. Search 2478. Address A. S. M. E., 29 West 39th St., New York.

Boilers F1-19 Use of Boiler Compounds or Kerosene Oil for Boiler Cleaning. Search 2482. Address A. S. M. E., 29 West 39th St., New York.

Economics F1-19 Labor Hiring and Discharging. A bibliography of 4 pages. Search 2510. Address A. S. M. E., 29 West 39th St., New York.

Economics F2-19 Depreciation and Amortization of Machinery and Machine Tools. A bibliography of 4 pages. Search 2545. Address A. S. M. E., 29 West 39th St., New York.

Foundry Equipment, Materials and Methods F1-19 Aluminum Castings: Remelting. A bibliography of 4¼ pages. Search 2581. Address A. S. M. E., 29 West 39th St., New York.

Fuels, Gas, Tar and Coke F1-19 Pulverized Coal. Search 2301. Address A. S. M. E., 29 West 39th St., New York.

Fuels, Gas, Tar and Coke F2-19 Burning Tan Bark Under Steam Boilers. A bibliography of 1 page. Search 2567. Address A. S. M. E., 29 West 39th St., New York.

Fuels, Gas, Tar and Coke F3-19 Calorific Value of Fuel Oils, A bibliography of 1 page. Search 2496. Address A. S. M. E., 29 West 39th St., New York.

Fuel Utilization F1-19 Furnaces for Green Bagasse. A bibliography of 1½ pages. Search 2578. Address A. S. M. E., 29 West 39th St., New York.

Heat F1-19 Utilization of Solar Energy. Search 2431. Address A. S. M. E., 29 West 39th St., New York.

Heat F2-19 Transmission of Heat Through Glass. A bibliography of 4 pages. Search 2461. Address A. S. M. E., 29 West 39th St., New York.

Heat F3-19 Heat Radiation and Convection. A bibliography of 3 pages. Search 2495. Address A. S. M. E., 29 West 39th St., New York.

Hydraulics F3-19 Flow of Oil Through Orifices. A bibliography of 1 page. Search 2563. Address A. S. M. E., 29 West 39th St., New York.

Hydraulics F1-19 "United States Water Power Resources." A bibliography of 6 pages. Search 2508. Address A. S. M. E., 29 West 39th St., New York.

Internal-Combustion Engines F1-19 Gas Turbines. A bibliography of 2 pages. Search 2547. Address A. S. M. E., 29 West 39th St., New York.

(Continued on page 718)

ENGINEERING SURVEY

A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

SUBJECTS OF THIS MONTH'S ABSTRACTS

Fencing for Factory Protection
Permanent-Mold Production
Alcohol Fuel Committee's Report
Coke Firing in Germany
Bucket Water Turbines
Waste-Water Turbines
Liberty Motor
Tosi Diesel Engines for Submarines
Steam-Engine Lubrication
Governing of Motor-Car Engines
Turbines for Mechanical Drives
Curtis Impulse Turbine
Wind Resistance of a Train
Limit to Wear of Steel Wheels
Rolled-Steel and Cast-Iron Wheels Compared
Pulverized Fuel for Locomotives
Safety Practice in Power-Press Work
Spontaneous Combustion
Determination of Efficiency of Turbo-Alternators
Measurement of Air Flow and Temperature
Status of Large Turbines

FACTORY MANAGEMENT

The Silent Watchman Over Industry. The necessity of plant protection against human destructive agencies has been forcibly emphasized by various occurrences during the period of the war, but even in times of peace there is an essential need of adequate protection for plants.

The article briefly discusses the problem of fire protection and then goes into considerable detail as to protection by fencing in the premises. Such fencing-in protects the plant against trespassers, with all the danger that they involve in the way of theft and increased possibility of fire.

Many types of fences designed to give plant protection are on the market. During the war the amount of such fencing sold to industrial plants was very large. In some instances the Government itself paid for the fencing, while in other cases it refused to award contracts until the fencing was installed by the company itself. The cost of fencing may be as high as $2 a lineal foot.

In addition to fencing, flood light was extensively used during the war. It has been estimated that during 1917 and 1918 some 100,000 flood lights were sold to American plants for protection purposes, but the sales fell off tremendously after the signing of the armistice. (*The Iron Trade Review*, vol. 64, no. 25, June 19, 1919, pp. 1609 to 1612, 6 figs., *g*)

FOUNDRY

A Permanent Mold or a New Method of Molding, F. B. Gordon. The author begins by justly pointing out that our modern methods of molding are to all practical purposes the same as those which were practiced by the Egyptians 4000 to 5000 years ago. From this he proceeds to a brief description of a discovery by William M. Hoffman, of Buffalo, N. Y., who claims that he has found a new molding material.

While exploring corundum veins in the Blue Ridge Mountains of North Carolina, he came upon a surface of combination amphibole and actinolite. These minerals belong to the same class as asbestos, with the addition of magnesia and other minerals of a refractory nature. It is claimed that with a proper binder, which is said to have been perfected, it is possible to use these materials for permanent molds. No data as to the method of using such molds, their life and way of restoring the mold face are given in the original article. (*Canadian Foundryman*, vol, 10, no. 6, June 1919, p. 147, *d*)

FUELS AND FIRING

The Alcohol Fuel Committee's Report. Abstract of the report of the Alcohol Fuel Committee appointed in October 1918 by the British Government.

The Committee consisted mainly of the nominees of Government Departments, not necessarily fuel experts, but appointed to survey the situation, to estimate the importance of the problem and to report as to the best steps to be taken.

The report indicates that the climate in Great Britain is not well suited to the growth of most alcohol crops, but that synthetic production of alcohol is a commercial possibility. A spirit can be obtained from ethylene extracted from coal and coke-oven gases and it is estimated that the production of 100,000,000 gal. a year might be reasonably expected in Great Britain if the necessary facilities were given for the development of the method.

The statement is made, however, that the main sources of power alcohol must be found in the vegetable world in tropical and subtropical countries.

The main conclusions of the report are that in order that the fuel may be available in quantities and at the right price, a material change must be made in many government regulations. The use of cheaper denaturants must be permitted, continuous distillation must be allowed and also simultaneous fermentation and distillation in the same building. These changes would occasion the abandonment of the present regulations for ascertaining specific gravity before fermentation.

The report also recommends the establishment by the government of a permanent organization to initiate and supervise experimental and practical development work on production and utilization of power alcohol. (*Motor Traction*, vol. 29, no. 748, July 2, 1919, pp. 5-6, *g*).

German Experience with Coke Firing of Boilers During the War

Coke Firing, Reichelt. Data on the present state of knowledge of coke firing in Germany, embodying apparently experience gained during war.

It is pointed out that a clear distinction should be made between gas coke and metallurgical coke. Gas coke is easier to ignite because its structure is less compact, while coke from coke ovens, especially that made from fat coals, has a compact structure and is less easy to ignite.

When burned, coke keeps the shape of the lump longer than coal. Coke is more difficult to bring to the state of incandescence, but it burns slower. It does not give off its heat with the same speed as coal and because of this, in order to burn the same weight of fuel one has to employ a larger grate and use a deeper fuel bed; its lower specific weight as compared with coal also makes a larger grate necessary.

The size of the lumps is essential. If the lumps are too large, the surface subject to the action of the air is too small to maintain the combustion process, at least if the draft remains within

the same limits. Metallurgical coke as it comes is usually in too large lumps. It is pointed out that the users of coke cannot be expected to crush it, as under present conditions it is impossible to secure crushing equipment, so that the coke should be crushed at the plants. The limits of size are indicated by the author as 10 mm. (0.4 in.) on the one hand to 40 mm. (1.6 in.) on the other.

The finer sizes, and in particular coke breeze, make too dense a layer and with ordinary draft do not provide for a sufficient contact with the air. Their combustion on a plain grate is possible only when special appliances are used.

As a rule, coke requires a stronger draft, which is due to the greater depth of the fuel bed and the resulting increased resistance to the flow of air.

The portable boilers easiest to equip for coke combustion are of the locomotive type, because of the powerful draft available. As a rule, in locomotive operation coke is mixed with coal in the ratio of 1 to 2.

Otherwise coke is but little adapted for portable boilers because of the lack of suitable draft.

For use on shipboard coke is likewise not well suited because the ship bunkers cannot take up as much coke as they would coal. Furthermore, coke is not as convenient as coal where operation of the boilers is of an intermittent character, as it is in river- and canal-boat transportation.

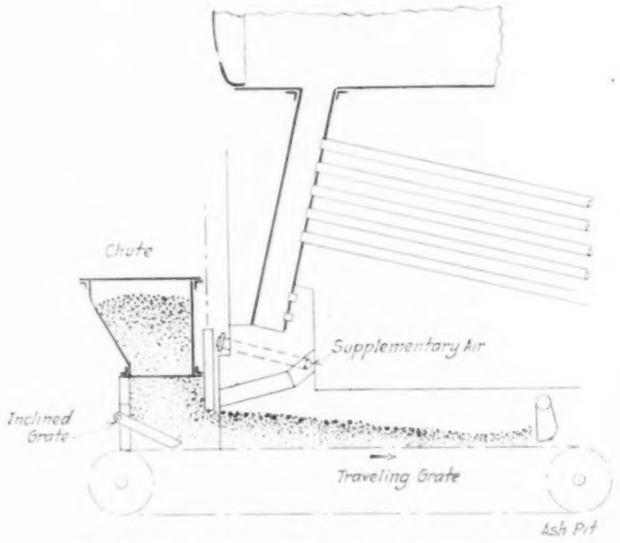


Fig. 1 Traveling Grate with Producer Hopper

It would appear, therefore, that stationary boilers are the main prospective consumers of coke.

It has been stated on many occasions, however, that with coke the boiler cannot deliver as much steam as with coal, especially when working at overload. This is due to the unsatisfactory flame formation resulting from the lack of volatile compounds (1 to 2 per cent in coke as compared with 20 to 30 per cent in coal) and also to the slower combustion of coke equivalent to a lower grate output. Hence, when it is impossible to increase the grate area, the output of steam is apt to fall off.

Likewise lower superheater temperatures have to be taken into consideration, as the exhaust gases enter the superheater at a lower temperature than when coal is used, due partly to the shorter flame and partly to greater excess air.

Coke firing makes greater demands on the fireman. It is recommended that in large plants those boilers that carry normal load be fired with coke, while the peaks of the load curve should be taken care of by boilers equipped for mixed or straight coal firing.

As regards the grate construction it was obvious that the traveling grates designed for coal would not do for coke. This problem was solved by subjecting the coke to a generator action. This means that the coke was brought to a bright glow in a separate hopper and from there delivered on to the traveling grate in a layer from 0.4 m. to 0.5 m. (1.31 to 1.64 ft.) deep, depending on the size of the coke. On the grate the coke was burned in a gradually decreasing depth, as shown in Fig. 1. At the end of the grate slag pockets were provided to prevent too much air from entering.

In order that the combustion should go on properly, it is important to maintain a powerful fire in the lower part of the auxiliary hopper, the purpose of which is to ignite the mass of coke lying above it. A sort of hearth is employed, so arranged that it has nothing to do with the advance of the fuel toward the

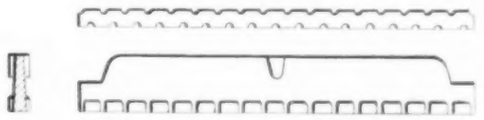


Fig. 2 Nozzle Grate Bar

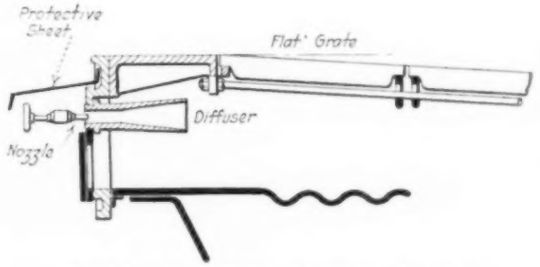


Fig. 3 Steam-Nozzle Underfeed Stoker

traveling grate proper, but lies more or less at rest on an inclined grate (Fig. 1) while the fuel for the traveling grate moves over it. The angle of inclination of the inclined grate is of material importance in this connection. If it is placed at too sharp an angle, the purpose desired will not be achieved and the fuel layer from the contact hearth will be carried away by the moving mass of coke, which will result in stopping the ignition of the coal in the hopper and "freezing" the latter.

The producer action of the auxiliary hopper, together with the deep layer of fuel, favor the production of carbon monoxide and hence flame formation, which is highly desirable. In order, however, to bring about a complete combustion of the gases, it is necessary to admit fresh air directly into the combustion space, which can be done most simply by means of tubes passing through the fire arch.

Several German concerns have devoted a considerable amount of effort to the study of coke combustion. Some of the results of this investigation were published in 1916 in a German publication; from that publication are taken the data of an evaporative test given in Table 1.

The following should be noticed in this connection: The heat balance is very good at the efficiency of 73 per cent, and with the factor of evaporation of 6.7 as compared to the efficiency of 71.5 per cent and the factor of evaporation of 7.5 of the same boiler with coal firing. Should the prices of fuel be proportional to the factors of evaporation and no other considerations enter into the question, the test would indicate that coke is just as good a fuel as coal.

The CO_2 content of 12.5 per cent is quite good and tends to

indicate that there was no particular excess of air. At the same time it should be borne in mind that this test was carried out under very favorable conditions. In particular the coke was quite carefully sorted so that the lumps were between 70 and 90 mm. (2.7 in. to 3.5 in.) in size and approximately uniform.

TABLE 1 EVAPORATIVE TEST OF A COKE-FIRED BOILER

Heating area of boiler, sq. m.	245.0
Grate area, sq. m.	5.3
Fuel, metallurgical coke	
Lump size, mm.	70 to 90
Duration of test, hr.	6
Feedwater, by volume, liters	23,900
Feedwater, by weight, kg	23,309
Feedwater temperature at boiler inlet, deg. cent.	80.3
Steam pressure, gage, atmospheres	10.8
Steam temperature, deg. cent.	367.7
Heat content of steam (according to Mollier tables), kg-cal. per kg	765.1
Heat content of feedwater, kg-cal. per kg	80.3
Heat of evaporation, kg-cal. per kg	684.8
Total weight of fuel, kg.	3475
Residues of combustion, kg.	435
Residues of combustion in relation to total fuel, per cent	12.5
Exhaust-gas temperature at damper, deg. cent.	305
Boiler-room temperature, deg. cent.	25
CO_2 content of exhaust gases, per cent	12.5
Draft at the damper, mm. of water	16
Steam generated per kg. of coke, kg.	6.7
Steam generated per sq. m. of heating area per hour, kg.	15.9
Fuel consumption per sq. m. of grate area per hour, kg.	109
Heat value of fuel kg.-cal.	6280
Combustible in the ashes, per cent	7.7

HEAT BALANCE

Efficiency of boiler and superheater, per cent	73.0
Smoke-stack losses (according to Siegert tables), per cent	14.5
Heat losses through unconsumed combustible in the ashes, per cent	0.8
osses through radiation, etc., per cent	11.7
	100.0

An entirely different picture is obtained when the tests are made with unsorted coke, varying in size from breeze up to 90 mm., with the breeze and dust content at about 50 per cent. In these tests the CO_2 content fell from more than 12 per cent in the previous test to as low as 3.5 per cent, a clear indication of the fact that the irregular size of the material caused an excess admission of air.

The other data of the test are essentially of the same character, which led the Rhine Association for the Inspection of Steam Boilers to the conclusion that in the present state of combustion engineering the use of unsorted coke on traveling grates is uneconomical, and further, that the irregularity of the combustion process leads to a considerably diminished output of the boilers.

It appears also that overloading the boiler leads to an excessive wear of the grates and cannot be maintained for any length of time. On the other hand, it appears that coal-firing installations can be converted to coke firing with comparative ease by the employment of steam jets as auxiliaries in the production of draft.

This arrangement can be used particularly well with fine coke, when either a grate with small interspaces may be used, or, still better, a so-called nozzle grate bar designed substantially as shown in Fig. 2.

In order to raise the air pressure under the grate the steam nozzle is led into the smaller end of a conical tube (diffuser) whereby the air compression is raised from 15 to 20 mm. of water. As shown in Fig. 3, the air suction occurs through the ring-shaped space between the nozzle and the tube. In accordance with the size of the furnace one or more nozzles may be used side by side.

The use of the Wilton grate and the evaporator grate in connection with water-tube boilers are also referred to. (*Zeitschrift fur Dampfkessel und Maschinenbetrieb*, vol. 42, no. 9, Feb. 28, 1919, pp. 57-61, 4 figs. d.)

HYDRAULIC ENGINEERING

Bucket and Waste-Water Turbines

INVESTIGATIONS ON BUCKET TURBINES, E. Reichel and W. Wagenbach. (*Zeits. Vereines Deutsch. Ing.*, 62, pp. 822-829, Nov. 23, and pp. 870-876, Dec. 7, 1918). In an earlier series of investigations (ibid., pp. 441 et seq., 1913) the behavior of various types of buckets *A* to *J* was examined under the same load and stress and the results were compared. With the exception of the *G*-bucket, all were obtained for a jet diameter of 30 mm.; jet distance (from center of wheel) of 275 mm.; and head of 100 m. The *G*-bucket was developed for a jet diameter of 40 mm. and for high speeds, other conditions being as before. Four different sizes of *G*-buckets were tested, all with nozzle and needle No. 6. The bucket notch was of the same width (40 mm.) in each case, thus permitting the same diameter of jet to be used throughout. Various numbers of buckets were mounted on the two sizes of disk, and so arranged that for each disk diameter the jet distance was the same for all sizes of bucket. From the results given in this paper it is possible to determine the most favorable construction for any new turbine using *G*-buckets in conjunction with No. 6 nozzle and needle, and working within the conditions and limits for specific speed determined by these investigations. Incidentally the investigations bring out a number of points concerning constructional details as well as considerable information relating to operating phenomena.

The linear dimensions of the four bucket sizes used are in the ratio 0.8: 1.0: 1.2: 1.35. At least four different numbers of buckets were tested for each size of disk and bucket. A complete statement is given of all the essential data, and two- and three-dimension curves are plotted showing the efficiency and other operating characteristics under various conditions. Owing to the number of variables concerned, reference must be made to the original for details. (*Science Abstracts*, Section B—Electrical Engineering, vol. 22, pt. 4, no. 256, April 30, 1919, Item 246, p. 120.)

WASTE-WATER TURBINES, H. Baudisch. (*Zeits. ges. Turbinenwesen*, Nos. 16, 17, 18, 1918. *Elektrot. u. Maschinenbau*, 36, pp. 547-548, Dec. 22, 1918. Abstract.) The energy in the effluent water of turbines can be utilized in waste-water turbines. If H = fall in meters, and c_a = velocity of outflow from suction pipe in meters per second, the effluent energy, hitherto wasted, is $k = c_a^2/2g$. According to the construction and speed of the turbine, k may be from 5 to 15 per cent of H. The waste-water turbine being connected behind the main turbine, the constructional problem is to build a compound turbine dividing the fall very unequally. Axial, radial, or axial-radial turbines may be used, and there is no restriction on the construction of the turbine, the shaft length or the method of building in. The only stipulation is that both turbines be full-stream machines. However, although there is no difficulty in building turbines for the same flow under different heads, it is very difficult to obtain the same speed in both cases. The problem is simplified if the turbine speeds be different and, say, a belt transmission be used to allow for this. If u be the ratio of the belt transmission, and n'_1, n'_2, the turbine shaft speeds, then $n'_1/n'_2 = u\sqrt{(H_2/H_1)}$. If $H_1 = 4H_2$, $Q'_1 = Q'_2/2$, and $n'_1 = un'_2/2$; and $u/2$ may be so chosen that the two turbines work at maximum efficiency. An arrangement offering many advantages is to use the waste-water turbine to drive a d.c. generator which acts as exciter to a three-phase alternator driven by the main machine and also serves station lighting and other d.c. circuits. If the two turbines are coupled (this being the cheapest arrangement), the governing gears must be suitably connected to maintain the distribution of head under all conditions. Such interconnection is effected easily where the electrical equipment is employed. The auxiliary turbine will always run faster than the main turbine; usually $n_{s_1}/n_{s_2} = 0.4$ to 0.8. A gain in power of from 5 to 10 per cent is obtainable by the use of waste-water turbines, the only additional investment being the cost of the latter. (*Science Abstracts*, Section B—Electrical Engineering, vol. 22, pt. 4, no. 256, April 30, 1919, Item 245, pp. 119-120.)

INTERNAL-COMBUSTION ENGINEERING

What the Germans Found from Tests of a Captured Liberty Motor

Liberty Motor, Otto Schwager. Account of a Liberty motor captured by the Germans with the English bomber Hyderabad No. 3, built at the Westland Aircraft Works.

The account is both descriptive and critical. Several interesting features are pointed out. Thus, in connection with the water circulation system, it is stated that on the basis of 80 liters (21 gal.) per hp.-hr. and a maximum engine output of 400 hp. a circulation of 8.9 liters of water per second would be required. In the article a curve is given showing the output of the water-circulating pump. This curve indicates that not more than half of that amount is actually obtained with a pressure of between five and six meters (19.6 ft.) of water. Therefore, as compared with the usual German practice, a radiator of about twice the usual dimensions is necessary with the Liberty engine, and a range of cooling in the radiator amounting to 10 deg. cent., in order that the necessary amount of heat should be carried off by the air.

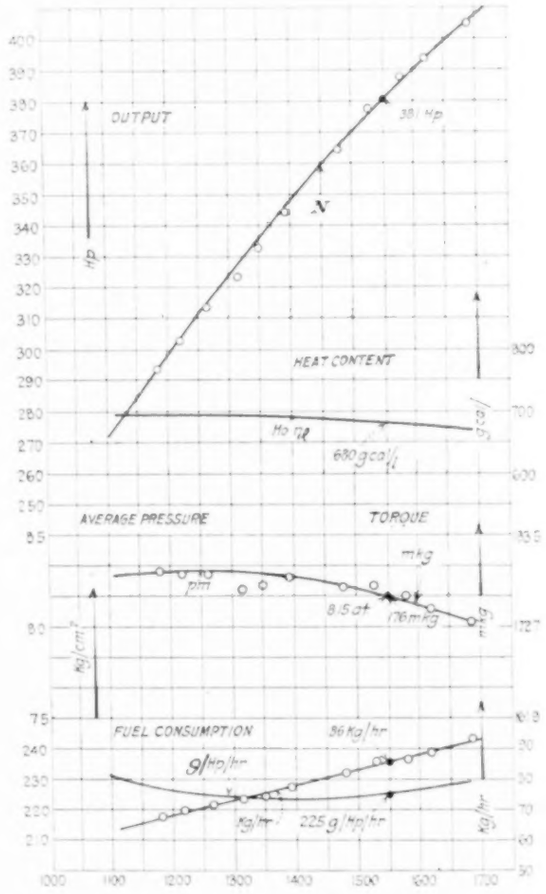


Fig. 4 Data of German Tests on the Liberty Motor

An interesting series of curves is presented in Fig. 4, which gives the test data of the captured motor with the standard Zenith carburetor.

The following comment is given: The curve of output, as function of the number of revolutions, is unusually good, which is ascribed mainly to well-selected valve-opening cross-sections together with moderate velocity of the flow of gases through the valves. The fuel consumption of 226 grams (0.49 lb.) per hp.-hr. is called very good for "foreign" (which means non-German) engines. The output at 1550 r.p.m. was 381 hp., which is somewhat less than the nominal rating of 400 hp., but it is stated that it is likely that an output of 400 hp. could be secured at that speed with a different setting of the carburetor.

The weight of approximately one kilogram per horsepower is said to be very good.

The general opinion of the motor is that its construction and weight are very good and that the ignition system is novel. The only objection made as regards the ignition system is in respect to the starting of the engine.

The direct drive of the air propeller is considered to be a basic defect of construction, in that with a motor of such a high output it is possible to secure an efficient propeller operation only by reducing the speed in revolutions. It is considered desirable that the motor should be equipped with a reducing gear.

In order to increase the output it would be further necessary to raise the speed of revolution of the motor as high as possible, say about 1800 r.p.m., which would, however, necessitate a redesign of the pistons and connecting rods. In this way, it might be possible to raise the motor output to about 500 hp., maintaining the propeller speed at its most efficient level and reducing the unit weight, including water and oil, to 0.9 kg. (1.9 lb.) per hp. (Der Liberty-Flugmotor, Otto Schwager, *Der Motorwagen*, vol. 22, No. 5, February 20, 1919, pp. 75-80, 20 figs., *e*)

Italian Diesel Engine for Submarine Use Developed During the War

Tosi Diesel Engines for Submarines. The Tosi Company has built a considerable number of Diesel engines for submarines both on the 2-cycle and on the 4-cycle principle. Table 2 for the first time gives in detail test results of these engines.

TABLE 2 COMPARATIVE DATA OF TESTS OF TOSI DIESEL ENGINES FOR SUBMARINES

	Full Load	Full Load	Three-quarter Load	Half Load	Overload
Type of engine	Two-cycle	Four-cycle	Four-cycle	Four-cycle	Four-cycle
Number of cylinders	6	8	8	8	8
Duration of trial, hr.	...	36	96	12	1
Power, hp.	1300	1300	950	650	1485
Revs. per min.	300	300	260	240	...
Fuel-oil consumption, lb. per b.hp-hr.	0.540	0.390	0.410	0.438	...
Lubrication-oil consumption, lb. per b.hp-hr.	0.0334	0.0180	...	...	...

The conclusions arrived at as a result of these trials were in favor of the 4-cycle type on account of lower fuel- and lubricating-oil consumption and greater flexibility. At the same time it should be borne in mind that they have built a considerable number of very large 2-cycle engines which are running quite satisfactorily and it is possible that for very large powers the 2-cycle engine may be at least as good as the 4-cycle.

The article for the first time gives drawings for certain interesting details of construction.

Thus, Fig. 5 shows the gudgeon-pin construction with the sleeve keyed on to the pin proper and forming the bearing surface. This sleeve permits of a reduction of pressure in the gudgeon-pin bearing from about 2000 lb. per sq. in. to 1400 lb. The bearing is force-lubricated by a supply of oil under pressure through the hollow connecting rod.

The piston crown is made concave to increase the efficiency of oil cooling (its outward shape being somewhat like that in the Willys-Knight engines built in this country).

Two exhaust valves per cylinder are provided but they are placed in separate cages and do not sit in the cylinder head as in the slow-speed engine. Although the diameter of each valve

is relatively small (there being two per cylinder), the valves are internally water-cooled, the water supply being by means of a spiral pipe attached to a spiral nut on the top of the exhaust valve spindle. The construction of the valve and its cage is shown in Fig. 6. The inlet valves sit in the lower face of the cylinder head. The main water-cooled exhaust connecting pipe is fitted internally with a light spiral baffle to prevent interference

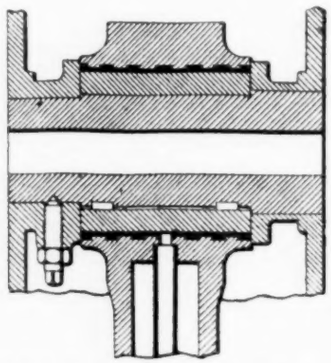


FIG. 5 GUDGEON-PIN CONSTRUCTION FOR TOSI SUBMARINE DIESEL ENGINE

of the exhaust of one cylinder with that from another, which is necessary since with an 8-cylinder 4-stroke-cycle engine two cylinders will exhaust at the same time at certain points in the revolution, as indicated by one of the diagrams in the original article.

The 4-cycle engine is not fitted with any starting device and is started electrically by the main propelling motors or by a separate starting engine. There are, however, certain objectionable

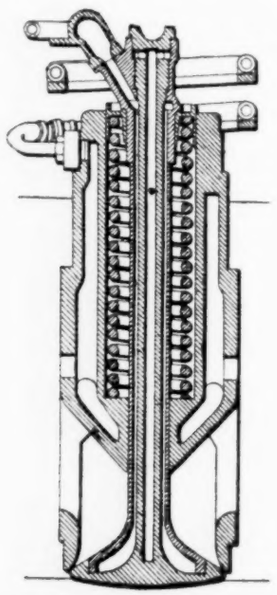


FIG. 6 VALVE AND VALVE CAGE IN TOSI SUBMARINE DIESEL ENGINE

features to such methods and a compressed-air auxiliary starting engine has been designed for starting by compressed air. This engine has three radial cylinders and drives a pinion with teeth engaging with the periphery of the flywheel. These teeth are slightly spiraled in order to keep in engagement as long as the starting motor is driving, but when the main engine picks up and becomes the driver the thrust of the spiral teeth pushes this pinion forward sufficient to throw it out of engagement with the flywheel. (*Engineering*, vol. 107, no. 2788, June 6, 1919, pp. 732-734, 8 figs., *de*)

LUBRICATION

ECONOMICAL LUBRICATION OF STEAM ENGINES, K. Schmid. (*Würtemberg Revisions-Verein, Geschaeftsbericht*, 1915. *Elektrot. u. Maschinenbau*, 35, pp. 194-195, April 22, 1917. Abstract.) The data presented are derived from material collected by inspecting a great number of working installations. Only in five engines among those investigated was there a really low consumption of lubricating oil; the minimum was 0.178 gram of cylinder oil and 0.23 gram of bearing oil. In order to obtain results applicable to any engine, the oil consumption must be referred to the actual engine dimensions rather than to the horsepower developed. The temperature of the cylinder walls and their area are of primary importance in determining the oil consumption. The piston speed is also an important factor; and so is the diameter of the low-pressure cylinder in multi-cylinder engines. If D_n = diameter of cylinder (low-pressure cylinder in multi-cylinder engine); s = stroke, both in meters; n = r.p.m.; and K = constant; then the consumption of cylinder oil in grams per hour is given by: $O_s = KD_n \times \pi \times sn/30$. Denoting by μ the term $K\pi/30$, we have $\mu = O_s/D_n sn$. In the five most economically lubricated engines, O_s = 99.1, 100.6, 164.5, 148, 180 grams per hour and corresponding values of μ = 1.275, 1.633, 1.48, 1.6, 1.6 respectively. The author concludes that μ may be as low as 0.8 or 1.0 before wear occurs. With $\mu = 1.6$ there is about 50 per cent saving in oil compared with present consumption, and this saving may be increased to 75 per cent if special efforts be made.

It is recommended that oil separators be installed in the exhaust, and that the separated oil be cleansed and used again for lubrication; also, that the exhaust pipes be drained and the superheat reduced. An allowance of oil on the basis of $O_s = 1.6\ D_n sn$ should suffice, and a premium may be offered to encourage economy. When using drip-feed lubricators with thick oil, the lubricator should be heated by locating it on a hot part of the cylinder, or by other means. Springs and valves are to be avoided in lubricators. Improved bearings and lubricators save oil. Graphite often makes possible important economy in oil. Suitable greases may replace considerable quantities of oil, especially in bearings. "Tar fat" oils are a useful substitute for petroleum oils in bearings but not in cylinders. The author considers that 90 per cent saving in cylinder oil is possible. A saving of 87 per cent in bearing oil has already been effected. (*Science Abstracts*, Section B—Electrical Engineering, vol. 22, pt. 4, no. 256; April 30, 1919, Item 230, pp. 114-115.)

MOTOR-CAR ENGINEERING

Motor-Car-Engine Governors of German Design

GOVERNING OF MOTOR-CAR ENGINES, Pretorius. Description of some of the governor devices developed in Germany.

The devices shown do not represent anything radically different from those used in this country. Of interest is the governor for aircraft motors diagrammatically shown in Fig. 7 the purpose of which is to cut out ignition in case the motor exceeds the desired speed of revolution. The underlying idea in this governor is that in the case of the rupture of the transmission system, the engine may run away to a dangerous extent. It should be borne in mind, however, that the cutting out of the ignition when the engine has reached a very high speed of revolution may produce dangerous stresses in the engine parts.

The device shown in Fig. 7 is so designed as to obviate this to a certain extent. At the normal speed of rotation the governor a, and the spindle b controlled by it, take the position indicated in the figure. As this speed is exceeded the governor takes gradually the position indicated in the figure in broken lines, and thereby the ignition apparatus is short-circuited by passing the current through the engine frame mass f, and the ignition system is put out of action. In order to restart the engine the spring g has to be brought by hand into its original position where it engages with the catch c.

Fig. 8 shows an interesting device, the purpose of which is to keep several engines running at the same speed. The speed indicators of various engines are provided with sliding contacts so

arranged that the ignition of the engine running beyond the desired speed is cut out until the engine reaches a certain lower speed.

It is not quite clear how the engine of which the ignition has

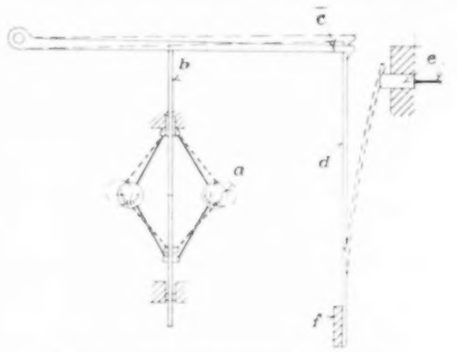


Fig. 7 Aircraft-Engine Governor

been cut out is restarted, unless this is done by the driven element utilizing the power of the engines still running. (Die Regelung der Kraftwagenmotoren, *Der Motorwagen*, vol. 22, no. 8, March 20, 1919, pp. 138-142, 5 figs.)

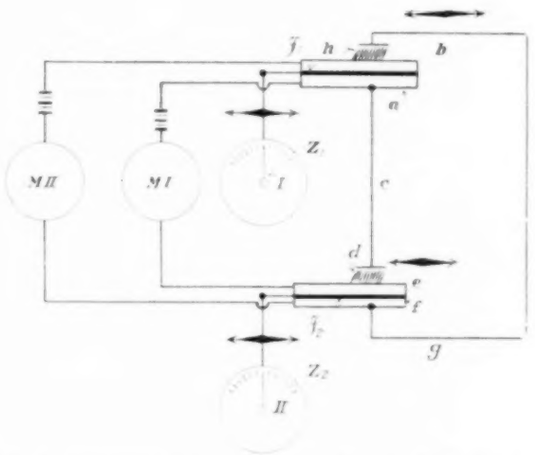


Fig. 8 Governor for a Multiple Engine Installation

PRIME MOVERS

Recent Developments in Design of Small and Medium-Sized Turbines for Mechanical Drives

Turbines for Mechanical Drives, R. R. Lewis. A comparatively recent development in the construction of small and medium-sized turbines are the units intended for the direct drive of pumps, fans, and other moderate-speed apparatus.

Turbines of this type are often located in basements and similar more or less inaccessible places where they are likely to receive very little care and attention, and must be therefore of a rugged and simple construction.

This can be secured by the utmost care in design and manufacture and by the use of the best material throughout, conditions which are very difficult to meet because it is necessary that the units should be of moderate cost and at the same time suitable for a wide range of operating conditions. For instance, in driving centrifugal pumps, the speed depends largely on the head under which a pump is to operate; and turbines for this service must run at speeds from 800 to 3600 r.p.m. Again, the steam pressure may be anywhere from 75 to 200 lb. or over, and the back pressure may be from atmospheric pressure to 20 or 30 lb., or the turbine may be required to operate with a vacuum.

To build a special turbine for each combination of conditions, of course, would be impossible; but practically the same result is secured by designing certain standard elements, a number of which can be combined to form a complete turbine that will exactly fit any particular case.

In the design of the type L turbine of the General Electric Company, the plan of construction involves the use of one, two, or three bucket wheels, and a variation in the length of the buckets and the arc of steam admission through the first stage nozzles, in addition to which the size of the steam and exhaust connections is varied and also the governor parts for regulation at different speeds.

The turbine (Fig. 9) is of the Curtis impulse type, in which the steam is given relatively high velocity by passing through a divergent nozzle. In entering the turbine the steam passes first through an emergency valve chest, if one is used; then through a steam strainer, and next through the governor valve. From this it enters the turbine proper through the first-stage nozzles, and after passing through the buckets of a single-stage turbine goes out of the exhaust opening.

The governor is of the centrifugal type and is mounted on the

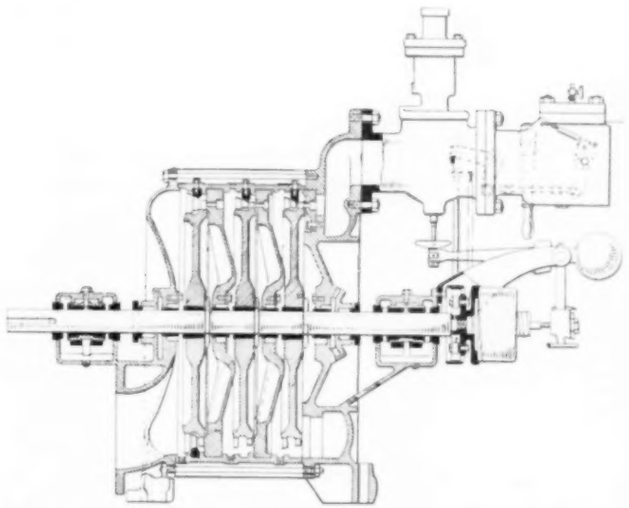


Fig. 9 Curtis Impulse Turbine for Mechanical Drive

end of the shaft. It operates, through a bellcrank, the governor valve of which is of the double balanced poppet type.

By means of a simple device the speed may be altered while the turbine is running, the governor continuing to exert full control at the altered speed. An emergency governor may be fitted to the machine to shut off the steam supply in emergency, and prevent excessive speed. Hand valves may be used for operation at two different steam pressures. These valves modify the effective capacity of the nozzles. (*General Electric Review;* vol. 22, no. 6; June, 1919; pp. 438-442; 12 figs. *d*)

RAILROAD ENGINEERING

Startling Savings in Power Achieved by Applying Aeronautical Experience to High-Speed Locomotives

The Wind Resistance on a Train, C. F. Dendy Marshall. This article is abstracted partly for the information which it contains and partly because it presents a good example of the benefits of what is known as the cross-fertilization of sciences, that is, the application in one branch of science of theory in another and apparently unrelated branch.

It has been known for a number of years that wind resistance affects the power consumed in propelling fast trains, but little or nothing has been done actually to take care of this condition. The author mentions only the fact that about 25 years ago on the South-Western Railway, Mr. Drummond made some of his

smokebox doors conical in shape, a plan followed on some continental railways. With the same end in view a wedge formation has been adopted on the Paris, Lyons and Mediterranean Railway.

It might be added here that the question of wind resistance attracted considerable attention in connection with the high-speed electric railway tests on the experimental line at Zossen, Germany, but the matter had not been placed on a scientific basis until quite recently—thanks to the work which has been done in connection with aeronautics.

The horsepower needed to overcome front wind pressure increases with the cube, not merely of the speed of the train, but also with that of what is called the "created wind," which in the case of express trains may easily exceed 80 m.p.h.

The resistance of the air to a surface moving normally to itself at high speed may be represented by the expression KAV^2, where A is the area exposed, V the speed, and K a constant. If A is measured in square feet and V in miles per hour, $K = 0.0033$. At 60 m.p.h. the value of this expression per square foot of transverse surface is approximately $1\frac{1}{4}$ hp., and at 80 m.p.h., 3 hp. If we know the "all out" speed in a calm, say, 70 m.p.h., numerical limits can be assigned between which the speeds will lie for any ratio of train to wind speed, such as are shown in Fig. 10. Here $V \cos \alpha$ represents the resolved part in the direction of travel over wind blowing with velocity V at an angle α to the rails.

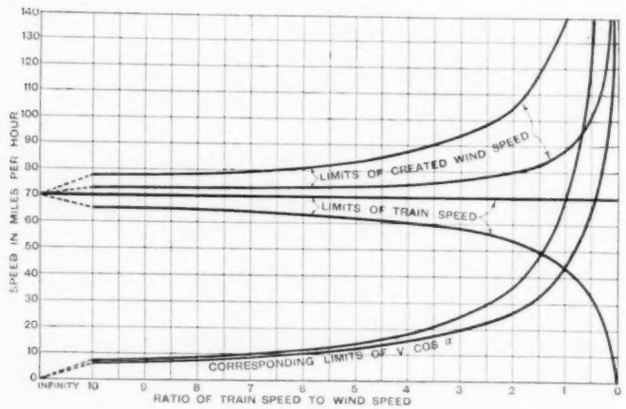

SPEED IN MILES PER HOUR
LIMITS OF CREATED WIND SPEED
LIMITS OF TRAIN SPEED
CORRESPONDING LIMITS OF V COS α
INFINITY 10 9 8 7 6 5 4 3 2 1 0
RATIO OF TRAIN SPEED TO WIND SPEED

FIG. 10 TRAIN-SPEED AND WIND-SPEED CURVES FOR FAST-MOVING TRAINS

The speed of the "created wind" increased with the strength of the natural wind and 80 m.p.h. is quite a moderate figure to take for it.

Aeronautical practice has shown what is the best shape for a body which is to be driven through the air at speeds of the order under consideration. The front should be quite "bluff," a sharply conical or wedge-shaped form not being at all the ideal to be aimed at. What is required is to reduce the transverse flat surface as much as possible, smooth off projections and use gentle curves parallel to the natural flow of the air.

The modern "extension" type of smokebox lends itself very well to modifications in this direction.

Take, for example, a large smokebox 5 ft. 8 in. in diameter. With the very slight bulge usually adopted for the door, the front may be taken as equivalent, as far as the pressure is concerned, to a flat surface—in this case an area a little over 25 sq. ft. The horsepower abstracted for $V = 60$ is 32, and for $V = 80$, is 75.

It is a simple matter to reduce these figures to a great extent. If the ring at the front end of the box is made only just large enough to carry the door, as shown in Fig. 11, or, say, 4 ft. 8 in. diameter instead of 5 ft. 8 in., the front surface is reduced by 8.12 sq. ft. The result is a clear saving of 10.5 hp. for $V = 60$, and as much as 24 hp. when $V = 80$.

But we can go further than this. By forming the door with a radius of something under 3 ft., instead of the usual one, which is frequently as much as 18 ft., we can produce a front door much superior from an aeronautical point of view, such, for example, as is shown in Fig. 12. It is reasonable to expect this smokebox to effect a saving of the order of 25 hp. when the "created wind" speed is 60 m.p.h. and 60 hp. when it is 80 m.p.h.

The author claims that the shape of the locomotive is deserving of careful study and that some modifications of such value as not only to be worth making in the case of new engines, but possibly even worth while to be introduced in the existing ones as they come into the shops for heavy repairs.

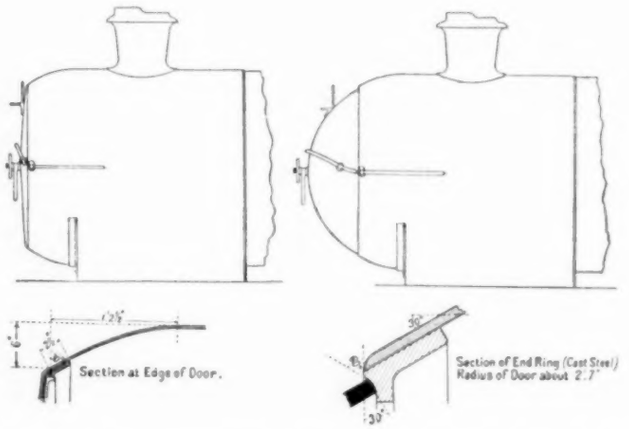


FIG. 11 (LEFT) LOCOMOTIVE DESIGN WITH REDUCED RING AT THE FRONT END OF THE BOX

FIG. 12 (RIGHT) IMPROVED SMOKEBOX DESIGN EFFECTING A GREAT SAVING IN AIR RESISTANCE

Credit is given to the Report of the Electric Railway Test Commission, New York, 1906. (*The Engineer*, vol. 127, no. 3207, May 16, 1919, pp. 473-474, *p*A.)

LIMIT OF WEAR OF STEEL WHEELS. A test was recently conducted by the testing department of one of the large railroads to determine whether or not steel wheels of $\frac{1}{4}$ in. below the present scrap wearing limit can be used with safety.

For this purpose four rolled-steel wheels which had been in service under locomotive tenders were selected from a lot of scrap wheels. They had treads worn from $2\frac{3}{8}$ to $2\frac{1}{2}$ in. below the new diameter or about $\frac{1}{4}$ in. above the limit mark.

The treads of two of the wheels, Nos. 1 and 4, were turned to a thickness of 1 in. or to the present scrap wearing limit. All flanges were turned to the minimum allowable thickness of 15/16 in. and with vertical surfaces and sharp fillets, similar to the worn conditions developed in service.

The M.C.B. drop-test machine was used for this test, the wheels being supported in a way that caused the entire thrust to be taken by the flange.

For static tests sections 1 in. thick were cut from each steel wheel and tested in a Riehlé testing machine in a manner shown in an illustration in the original article. The arrangement was such as to provide a loading which produced a thrust in a direction parallel to the axis of the wheel and similar to that which occurs in service.

In addition to this three cast-iron wheels were selected from among the scrapped wheels at a large wheel foundry and tested in a manner similar to the steel wheels.

The results showed a decided superiority of steel over cast-iron wheels under the drop test and indicated that a reduction of the thickness of the tread does not affect the strength of the flange in rolled-steel wheels.

The failures of the 1-in. test sections were similar in that all broke in the same way at about the same place. In no case did the break occur at the throat of the flange or at the thinnest section of the tread, but always to one side of the thinnest section toward the center of the tread.

The results of the drop test indicate that the rolled-steel wheels whose treads were turned ¼ in. below the present scrap wearing limit, with flanges of the minimum allowable thickness, have decidedly stronger flanges than cast-iron wheels, the flanges of which are worn to the minimum allowable thickness.

The nature and similarity of the failures of the 1-in. sections indicate that there is no weakening effect on the flange proper caused by reducing the tread thickness. There is, however, a weakening of the tread due to its own reduced section. (*Railway Mechanical Engineer*, vol. 93, no. 7, July 1919, pp. 437, 438, 6 figs. *ep*)

PULVERIZED FUEL FOR THE RAILWAYS. Abstract of a report presented by a special committee at the 11th Annual Convention of the International Railway Fuel Association, held in Chicago the week of May 19, 1919. This report is based on tests made under regular service conditions just before the war.

A carefully conducted test between two engines of the same class, one burning pulverized coal and the other hand-fired, showed a saving of 23 per cent in fuel burned in favor of pulverized coal.

The main difficulties encountered were the slagging over of the fuel sheet and burning out of the brick arch, and the first was largely overcome by an air jet to blow off the slag accumulations.

The cost of replacing the arch brick largely overcame the saving in fuel, in addition to which there was a delay to the locomotive. In the end a comparison of total costs of hand firing vs. pulverized-coal firing on the locomotives tested, which include cost of pulverizing, cost of handling, cost of arch maintenance, interest and depreciation, showed the hand firing to be most economical. It was, however, thought possible to design a firebox that would avoid burning out the brick arch.

On the other hand, pulverized fuel had been burned satisfactorily, generating all the needed steam and with good control.

The report recommends that experiments should be made to determine if thoroughly air-dried coal ground to the fineness of, say, coarse granulated sugar, and burned in suspension, in specially designed furnaces, will not produce greater overall economy.

It is further suggested that it might be possible to arrange a pulverizing or stoking device that would prepare any grade of coal on the tender and deliver it to the firebox in the pulverized form. (*Power*, vol. 49, no. 25, June 24, 1919, p. 997, *g*)

SAFETY ENGINEERING

Safety in Power-Press Work Without Reduction in Output

SAFETY PRACTICE IN POWER-PRESS WORK. Accident records show that more injuries occur on power presses than on any other machine except, perhaps, the circular saw. In practically all press accidents the operator's fingers are caught under the ram at the point of operation. This may be due to the press repeating, or the operator leaving his hand between the dies as the ram descends, or an unexpected stroke caused by accidental tripping.

Analysis of the accidents tends to prove that to prevent them a study of the operation of each press must be made to eliminate if possible the need of the operator placing his hands between the dies, or if this is not practicable, to install a guard which will prevent the operator's hands being caught between the dies when the ram descends.

The most effective way to remove the operating-point hazard is by using the automatic feed, but for some operations it is difficult to develop such a feed.

The same guarding of presses should begin with the design of the dies and it is essential to design them so that the operator need not put his hands between them. The use of sliding, revolving or dial dies as compared with the old types where each separate piece had to be put under the die by hand has already been a great step forward in the direction of insuring greater safety. But even in hand-fed dies increased safety may be secured by cutting away superfluous metal from the die block, thus allowing more space for the fingers. Wherever possible the die should be designed so as to permit the operator to grasp the material by the sides instead of at the top and bottom. Whenever possible guards should be attached to the dies.

The original paper, which is extensively illustrated, discusses in some detail the operations on power presses and cites interesting instances of devices used to increase the safety of operation.

The writer comes to the general conclusion that properly designed safeguards actually increase production. It is true that in some instances the only safeguards available are such as decrease production to a certain extent in units per hour, but even in such cases it must be remembered that without the guard production may be entirely stopped by an accident to the operator. Furthermore, if a "green" operator is put on the machine, it will require considerable time to attain the rate of output, so that in the end any decrease in production due to the use of safeguards will be quite small in itself and amply compensated in other ways. (*American Machinist*, vol. 50, no. 25, June 19, 1919, pp. 1177-1184, 29 figs., *gp*)

Spontaneous Combustion, What It Is and in What Materials It Occurs

SPONTANEOUS COMBUSTION, Watson Smith. Discussion of the nature of spontaneous combustion and factors contributing to its occurrence.

The following definition is given: Spontaneous combustion is caused by the physical and chemical capacities of certain carbonaceous and organic matters to condense on their surfaces gases and moisture. The amount of gas thus condensed varies with the chemical nature of the gas and is also dependent on the degree or subdivision of the absorbent substances. If the atmospheric oxygen is the gas thus condensed, evolution of heat accompanies the condensation, and if this occurs within a bad conductor of heat, the heat accumulates and eventually gives rise to combustion.

As a result of this, it is pointed out that coal containing pyrites is particularly inclined to ignite when in a damp state. It is also pointed out that air shafts through the masses of coal on board ship actually favor the tendency of the coal to spontaneous combustion. On the other hand, explosions of coal gas, which may accumulate in ship bunkers, are best eliminated by passing currents of air directly over the coal and then into the open. The extinction of bunkers on fire by means of carbon dioxide was held by the British Commission of Inquiry (about 1890) to be impracticable, as this gas has no cooling effect, and the Commission was inclined to give preference to the employment of steam and water.

There are a number of contributing causes which may lead to spontaneous combustion. Thus, it is stated that fires may arise through accidental contact of water with stocks of quicklime. It has also been found that finely ground charcoal placed in a barrel attained a temperature of 75 deg. cent. after 15 hours, and after 20 hours ignition took place. Having once had the management of a wood distillery, the writer testifies to the need of great precautions to avoid the danger of outbreaks of fire in the charcoal sheds.

The statement that wet cotton is liable to break out in combustion is improbable, but a spark getting into a bale will smolder for a long time and may cause a fire eventually, which may then be improperly ascribed to spontaneous combustion.

Greasy cotton is particularly dangerous as most fatty oils absorb oxygen rapidly with generation of much heat. Heavily weighted silk is dangerously liable to heat up and burn, two cases of such occurrences being definitely known.

The firing of haystacks is also an undoubted fact. Among other things, it has been shown that fermentation caused by bacteria in hay is responsible for such occurences, and in Holland a preventative is found in common salt which is scattered between the layers of hay during the erection of the stacks. Tschirch, who gives a theory to account for the spontaneous ignition of hay, recommends thorough drying of the hay before stacking,—a process designed

to minimize enzymic action, and also thorough aeration of the stacks.

From other data collected in the paper it appears that quite a large number of substances have the ability to take fire spontaneously under certain conditions. Among such materials are mentioned tobacco, lupulin (an extract of hops), aniline dyestuffs, dried fish, bone dust, wool, and various chemicals. The paper is of particular interest in connection with the question of storing and transportation of the materials above enumerated, particularly on shipboard. (*Journal of the Royal Society of Arts*, vol. 67, no. 3474, June, 1919, pp. 500-507, *g*)

STEAM ENGINEERING

How a Difficult Problem in Measuring Air Volume Has Been Solved

DETERMINATION OF THE EFFICIENCY OF THE TURBO-ALTERNATOR, S. F. Barclay and S. P. Smith. The efficiency of the turbo-alternator is usually expressed in terms of the rate of steam consumption in relation to the output of electrical energy. Because of this the purchaser has little direct economic interest in the accurate determination of the efficiency of the alternator, which is, nevertheless, a matter of considerable interest, as it indicates the quality of the active materials employed and the degree of excellence of the design.

The authors point out that in determining the efficiency of alternators stray losses are either deduced in some conventional way or ignored altogether, but as the size of the alternators becomes larger the stray losses become of greater importance and furthermore cannot be conveniently determined on account of the difficulty of making tests.

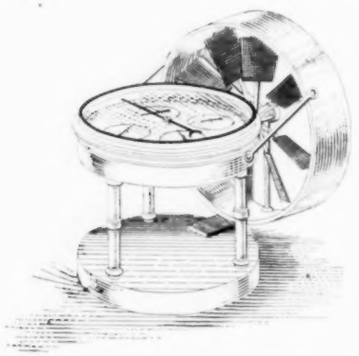


FIG. 13 NEGRETTI & ZAMBRA ANEMOMETER

The present paper shows how stray losses can be deduced from measurements of the cooling air flowing through the alternator and also what precautions should be taken in order to avoid securing misleading results.

The electrical part of the paper, while of considerable interest in itself, lies beyond the strict scope of MECHANICAL ENGINEERING, but the part referring to measurements of air volume and temperature is of general interest.

For measurement of air velocity the writers consider four methods—the pitot tube, venturi tube, electrical methods, and the use of an anemometer. For purposes of the tests carried out by the writers the anemometer shown in Fig. 13 was used. Because it was found that a well-made instrument when properly handled gave sufficiently accurate results and further on account of the air flow being variable in direction, the anemometer is probably better adapted to read the absolute value of the average velocity at a given point than are more exact instruments.

The two inherent defects of the anemometer are due to the effects of friction and the inertia of the moving parts. The effect of friction on the reading is, however, slight when the velocity of the air is considerable and the velocity of the air discharge from a turbo-alternator is of the order of 2000 ft. per min. With an instrument of the kind used by the authors measuring about 2.6 in. over the tips of the vanes, the frictional effect is not more than 3 per cent of the vane-wheel speed, so that even an appreciable error in the correction for friction has only a negligible effect on the result. The effect of inertia is of appreciable importance only when the air flow is variable.

The authors have checked the accuracy and consistency of the anemometer in several ways. When a fan delivers air to a given system of ducts, the volume of air discharged is a linear

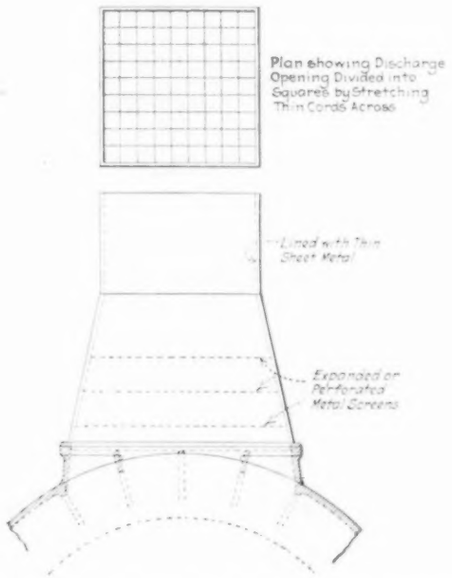

Plan showing Discharge Opening Divided into Squares by Stretching Thin Cords Across
Lined with Thin Sheet Metal
Expanded or Perforated Metal Screens

FIG. 14 TEMPORARY DISCHARGE TRUNK USED TO FACILITATE MEASUREMENTS OF AIR VOLUME AND TEMPERATURE

function of the speed of the fan—that is, if V is the volume of air delivered in unit time, and n is the speed of revolution of the fan, then $V = Kn$, where K is a constant. Therefore, by running an alternator at various speeds and measuring the air volume in each case, the accuracy of the anemometer readings is established if they bear a constant ratio to the speed of rotation. The authors have found that the results obtained in this way are very satisfactory, as is shown in the typical case given in Table 3.

TABLE 3 TYPICAL TEST RESULTS SHOWING CONSTANT RATIO BETWEEN VOLUME OF AIR DELIVERED BY FAN AND SPEED OF ROTATION (MACHINE NO. 7634)

V	4,550	7,200	8,550	10,900
n	1,500	2,400	3,000	3,600
K	3.033	3.000	2.583	3.028
Variation from mean value of K, per cent	+0.73	−0.37	−0.93	+0.56

The accuracy of the anemometer was further checked by comparing the known loss in the alternator with the heat energy being carried away by the air; and still further, two new instruments calibrated at the National Physical Laboratory and an instrument that had been in use for two years were mounted in succession in a given position at the discharge outlet of an alternator and were run for varying periods, during which the speed of the alternator and the load were maintained as constant as possible. All these tests simply indicate quite a satisfactory performance on the part of the anemometers.

The measurement of the volume and temperature of the air discharged from the alternator proved to be no easy matter. The first difficulty encountered was a consequence of the great varia-

tion in the velocity of the air at the discharge opening of the alternator due to the peculiar shape and disposition of the openings in the stator core and frame and also of the rotation of the rotor tending to cause the air to discharge obliquely instead of vertically.

In order to equalize the air flow a temporary discharge trunk

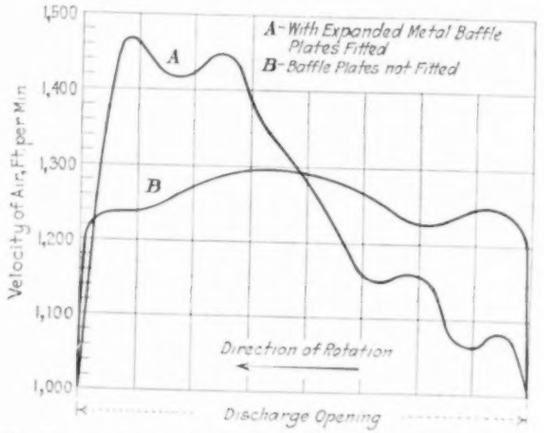


Fig. 15 Curves Plotted from Pitot-Tube Readings Taken at Opening of Temporary Discharge Trunk

such as shown in Fig. 14 was fitted and the air velocity measured by traversing the pitot tube across the discharge opening. The results obtained are shown by curve *B* in Fig. 15. To equalize the air velocity still further, close-mesh expanded-metal baffle plates were fitted in the trunk. Curve *A* in Fig. 15 shows the improvement obtained. There is still some variation, yet if the anemometer readings are taken at fairly frequent intervals, the average velocity can be found with a sufficient degree of accuracy. The resistance of the expanded-metal baffles to the flow of air was found to have no appreciable effect on the temperature of the alternator.

For the accurate measurement of the air volume it was found desirable that the discharge opening should be divided into squares not much larger than the overall diameter of the anemometer. This can be done by stretching thin guards across the trunk as shown in Fig. 14 and taking the anemometer reading over each square. For small and medium-sized machines the squares could conveniently be made with the length of side of 4 in., but for very large machines the size might be increased somewhat to avoid taking an unnecessarily large number of readings. A certain error is introduced into the readings by the delay in starting and stopping the anemometer, and also as a consequence of the manipulation of the catch that throws the recording dials in and out of gear interfering locally with the air flow. These difficulties can readily be overcome by moving the instrument rapidly from square to square without stopping it, and the average value of the air velocity is found by dividing the total reading by the number of squares. The authors have found a slight but appreciable effect in adopting this safeguard. It is desirable to run the anemometer for an appreciable period over each square, 15 sec. being the minimum desirable time, and a longer period up to one minute being preferable when circumstances permit.

The paper discusses various corrections to be made, such as effect of temperature on air density, effect of atmospheric pressure on air density, effect of humidity on air density and specific heat, and effect of temperature on specific heat.

The discussion, which was quite extensive, dealt mainly with the electrical part of the paper. (*Journal of the Institution of Electrical Engineers*, vol. 57, no. 281, April 1919, pp. 239-314, 11 figs. in the paper and 3 in the discussion, *eA*)

The Large Turbine Has Come to Stay

Status of Large Turbines. Report of Prime Movers' Committee of the National Electric Light Association.

A consideration of the practical limit in size of single-shaft machines, so far as the questions of design enter into the problem, indicates that, in general, higher efficiencies at equal or less cost per kilowatt output can be obtained as the size of the unit is increased, particularly in capacities up to 30,000 kw., but although one single unit of 45,000 kw. capacity is now in service it cannot be assumed that the size of single-shaft units can be increased indefinitely.

It would appear in the opinion of the committee that with the present prevailing frequencies and speeds and the recognized factors of safety, efficiency and cost, the size of systems today will hardly warrant units larger than 30,000 kw. capacity. The increase of percentage which the individual turbo-generator bears to the total generating capacity of a system make the reliability of this type of machine a matter of much more importance from the operating standpoint than it was previously considered, and it is becoming increasingly onerous on account of overhead charges to safeguard this capacity.

In this connection it is stated that certain of these large machines have records of continuous performances and output which surpass anything previously considered possible. For example, one of the 25,000-kw. units has completed two 77-day runs at 67 per cent load factor in the first instance and 70 per cent in the second, without shutdown.

As regards causes of troubles in units of 20,000 kw. and over, certain features of design appear to be the most frequent source of trouble. Labyrinth packings and thrust bearings belong to this class, also excessive vibration of parts, breaking of buckets and dangerous rubbing of stationary and moving elements, which, in extreme cases have resulted in permanent deflection of shafts. The most serious situation, however, has been the number of recent turbine-wheel failures.

In general, records of operating performances of these larger units tend to indicate that as high a standard of performance may be expected from them as had been obtained earlier from machines of smaller capacity. The following statement is reproduced verbatim: "The situation is now a critical one, and while any definite statement at this time would be premature, the committee wishes to indicate the necessity for early action both in safeguarding against further possible failures of machines now in operation and in definitely reaching solutions of those problems which involve important features of design and construction."

In the discussion which followed, W. L. Abbott, Mem. Am. Soc. M. E., chief engineer of the Commonwealth Edison Co., Chicago, stated that although a number of failures had occurred in large machines, nothing in the situation warranted distrust of the large units, and the trouble was due to what may be considered as incidental faults.

W. S. Finlay, Jr., Mem. Am. Soc. M. E., of the Interborough Rapid Transit Co., New York City, pointed out that his company had in operation three 30,000-kw. and one 60,000-kw. reaction turbines, but as the stations were respectively of 205,000-kw. and 195,000-kw. capacity, the huge machines were really comparatively small units considering the total station capacity. (Report of Prime Movers Committee of the National Electric Light Association, abstracted through *Power*, vol. 49, no. 21, May 27, 1919, pp. 832-834, *gA*.)

Flow of Steam Through Pipes, A. Stodola. (*Zeits. Vereines Deutsch. Ing.* 63, pp. 31-36, Jan. 11, and pp. 96-100, Feb. 1, 1919.) Describes experiments on the forms of the stream lines of high-pressure steam flowing in pipes of various shapes. The experiments are based on observations with pitot tubes at various distances from the axes of the pipes and at different positions along their lengths. (*Science Abstracts*, Section B—Electrical Engineering, vol. 22, pt. 4, No. 256, April 30, 1919, Item 233, p. 116.)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

MECHANICAL ENGINEERING

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

A Tribute to Mr. Wellman

It was my happy privilege to be a close friend of Mr. Samuel Thomas Wellman; to be associated with him in many organizations, and often to be his companion in traveling through Europe and the Orient. Throughout this period, covering more than a third of a century, my affection and admiration for him constantly deepened.

As one of the constructive men in this, the steel age, Mr. Wellman was known, not only in this country and in Europe, but throughout the world. I remember an incident when visiting the great steel works at Hankow, China, a few years ago. The Chinese works manager was conducting me through the plant, and when we came to one of the charging machines recently installed in connection with the heating furnaces, and stood watching the powerful arm reach into the oven as though it were human and handle the white-hot ingots, the manager remarked, "This machine is from America, and the invention of Mr. Wellman." It was indeed a pleasure to say to him that the inventor was one of my best friends.

Mr. Wellman was intensely devoted to the work of his profession; yet because of his exalted principles and his broad view of life, he was interested in all that pertained to the uplift of his fellow men.

Holley, Fritz, Wellman—a trio of contemporary engineers and pioneers in the steel industry! They have passed from among us, but because of their notable achievements and their splendid characters they will continue to live in the hearts of all those who knew them, and to be an inspiration for good as long as industry exists.

AMBROSE SWASEY.

What Are Your Ideas?

Is the membership of The American Society of Mechanical Engineers making the best use of its opportunity to have its views on the affairs of the Society and the conduct of those affairs considered and incorporated in the report of the Committee on Aims and Organization?

The tentative report of this Committee was presented at the Spring Meeting in Detroit and was discussed at three sessions: at the first session the attendance was reasonably large; at the second session there were only 37 present; and at the third session not half that number.

Does this mean that the Society is satisfied with its present aims and organization and not interested in its future development?

That cannot be, for they are of course interested.

Then why not give some evidence of it and take part in discussing the report and offer suggestions?

The report was published in full in the July number of MECHANICAL ENGINEERING, (page 601), together with changes suggested at the Spring Meeting and a summary of the discussion. It is the duty of every member of the Society to read the report and the discussion carefully and to give the Committee on Aims and Organization the benefit of his views. This should be done at once, for between now and the Annual Meeting, early in December, the committee must prepare its final report, after which necessary changes will be made in the Constitution and By-Laws.

The Society will have had a full year to make up its mind what it wants to do in the future. If it has not made up its mind it will be the fault of the members of the Society.

These are days of great changes in almost every walk of life. The Society desires to keep abreast of these changes in order that it can render the service desired of it. It is then the duty, the immediate duty, of the members to send on their ideas, and their suggestions of the things they would like to see the Society do,—or forever after to hold their peace!

M. E. COOLEY,
President.

International Standardization

Prof. Comfort A. Adams, Chairman of the American Engineering Standards Committee, has recently returned from France and England, where, in company with H. M. Hobart, also a member of the Committee, he investigated the work of standardization societies and the possibilities of establishing coöperative relations with them.

In this country, according to Professor Adams, the work of engineering standardization has up to the present time been conducted largely by independent organizations, and, although in some instances there has been fairly effective coöperation between organizations with overlapping of interests, this has been entirely voluntary and without any well-established coördinating central body. The result has been not only much confusion resulting from conflicting standards, but also in many cases the task of standardization has been undertaken with more energy than knowledge of the requirements of the work.

Standardization is a task which should either be thoroughly done or not at all. In fact, many of the efforts in this field have been largely wasted. It is impossible, for example, for any organization to enforce standards, and the only way to bring them into universal use is by enlisting the interests and services of all of the organizations involved in their application.

The need of coördination in this field has been increasingly felt for some years past, and about two and a half years ago the four national engineering societies and the American Society for Testing Materials laid plans for establishing the American Engineering Standards Committee, whose formal organization took place in October 1918. The Committee is now undergoing reorganization to the end that other societies interested in the work may be admitted, and the proposed reorganization has been fully reported in MECHANICAL ENGINEERING for July (p. 638).

Standardization abroad is also receiving considerable thought. In France the organization is called a Permanent Commission on Standardization, and is appointed by the Minister of Commerce. In Holland the organization is known as the Normalization Bureau. In England it is the Engineering Standards Association. In Switzerland a similar organization is contemplated, but it has not as yet been perfected.

The organizations of Holland and France are of comparatively recent origin, but the British association has been in operation about eighteen years and is doing an enormous amount of very important work, having secured the confidence of the government and many large organizations.

Professor Adams points out that the final outcome of this movement of world-wide organization in the field of engineering standardization is likely to be accomplished in somewhat the following manner: First, the organization in each country of a national coördinating body covering the entire field of standardization; and second, the organization in each section of that field of an international body coördinating the national sections.

At the present time such an organization exists in the electrical field. It is the International Electrotechnical Commission, and an attempt is now being made to bring about a similar organization in the aircraft field, and also in the field of testing materials.

A development of such a scheme of organization will mean much to the world's industry, to the increase in the productivity of labor, to international commerce, and to the establishment of commercial ties and better international feeling.

Screw Thread Commission Sails for Europe

The work of the Screw Thread Commission in connection with the standardization of screw-thread terminology, shape of threads, systems of threads and couplings, and methods of thread measurements and tests has been referred to in several of the recent issues of MECHANICAL ENGINEERING. In the April number it was stated that the Commission believed that an international conference would be necessary in order to provide a basis for arbitrary recommendations. Such an international conference will soon be held, for a delegation representing the Screw Thread Commission recently sailed on the U. S. S. *Leviathan*, which was bound for Brest, France. Upon their arrival the party will proceed first to Paris and then to London, where arrangements have been made for a conference with the British Engineering Standards Association. The delegation was to have been headed by Dr. S. W. Stratton, Director of the Bureau of Standards and Chairman of the Commission, but at the last moment he found it impossible to sail. The remaining members of the delegation are: Lt.-Col. E. C. Peck, Vice-Chairman, representative of the U. S. Army; Capt. John O. Johnson, representative of the U. S. Army; Commander L. B. McBride, representative of the U. S. Navy, and at present attached to the American Embassy, London; F. O. Wells, representative of the A. S. M. E.; Luther D. Burlingame, representative of the A. S. M. E., alternate for James Hartness; H. L. Horning, representative of the S. A. E., alternate for E. H. Ehrman; Earle Buckingham, representative of the S. A. E., alternate for H. T. Herr; and H. W. Bearce and Lieut. Robert Lacy, Technical Secretaries.

A New Attitude Toward Increased Production

In the last number of MECHANICAL ENGINEERING reference was made to the resolutions adopted by the American Federation of Labor at its Atlantic City meeting (page 629) recognizing the importance of research work as the basis for industrial development. The significant passages in these resolutions were those acknowledging the necessity for increased productivity as "a most potent factor in the ever-increasing struggle of the workers to raise their standards of living." In other words, to state it conversely, that the welfare and success of workers cannot result from restriction of output so long advocated by many labor organizations.

Coincident with this action by the American Federation of Labor was an incident of similar import, even if of smaller moment, which occurred at the Industrial Relations Session of The American Society of Mechanical Engineers at Detroit. This was a statement during the discussion by Mr. Boyd Fisher, Consulting Engineer in Management, that the officers of three labor unions had agreed to employ a firm of consulting engineers jointly with their employers, to install systems of scientific management.

While this may be an isolated case—merely a straw, perhaps—this attitude has undoubtedly been helped by and is complemental to the recent movement toward shop committees, whereby workmen may share in the management of a business to a greater or less extent as it affects their own interests. It indicates a willingness on the part of labor to accept methods for promoting increased production, *provided* it may have a share in the determination of these methods and in the allotment of gains.

Many features of this matter were ably brought out by the papers and discussion at the Detroit meeting, including the fact that the first shop committee was probably organized by Mr. H. F. J. Porter, Mem.Am.Soc.M.E., in 1903-4, at the plant of the Nernst Lamp Company, Pittsburgh, although such organizations have not been generally accepted as a foundation for harmonious relations in industry until very recently.

Enemy Opinion of the Liberty Motor

Toward the end of the period of hostilities the British bomber Hyderabad No. 3, built by the Westland Aircraft Works, fell into German hands. The engine, which was a Packard-built Liberty 12 of the standard army type, was apparently uninjured and gave the German engineers full opportunity to investigate its construction and performance ability. In this issue of MECHANICAL ENGINEERING are reproduced some of the results secured by them and published in a German technical periodical, *Der Motorwagen*.

It is hardly possible to suspect the Germans of partiality to the production of our War Department, which makes their opinion particularly interesting.

There is no doubt but that the German engineers were most favorably impressed with the design and performance of the engine. Their tests have confirmed practically along the whole line the results of similar tests made for example at McCook Field by the Aircraft Engineering Department of the War Department and published by special courtesy of the War Department in the March issue of this journal.

In fact, the only serious criticism made by the German engineers is that with a motor of such tremendous power, direct propeller drive was used. This criticism, however, has nothing to do with the design of the motor itself, and, as a matter of fact, is by no means new to our own engineers, as a vast amount of work was done by the Aircraft Engineering Department in the United States along lines of developing a reduction transmission for aircraft propellers to be used with the Liberty motor. Not only that, but at the time when the armistice was signed, a most interesting design was actually developed and extensively tested out and would have been probably used had not the armistice brought about a slowing down of the work of production and development.

Particular attention is called to the German data on the fuel consumption of the Liberty motor, which, if anything, are even more favorable to the motor than similar data officially published in this country.

Another First Flight

Particulars regarding the British giant dirigible R-34, which completed its round trip across the Atlantic on July 13, have been given by the column and page in the daily press, but should be recorded nevertheless as another of the remarkable demonstrations in aviation which have occurred this season in such rapid succession.

From an engineering standpoint this was a vivid and spectacular demonstration of the great value of the research activity of the Allies during the war. By united effort of the French, British and American engineers and chemists, the unwieldy and unreliable gas bags of pre-war times have been transformed into mighty dirigibles, larger than anything that the world believed to be possible only four or five years ago. A great contribution of American engineering toward the development of lighter-than-air machines lies, of course, in the perfection of a method for

producing on a commercial scale helium gas, the use of which in dirigibles is expected to revolutionize ultimately the whole art by making balloon fires and explosions practically impossible, the need for which was so shockingly demonstrated by the recent explosion of the dirigible at Chicago. (See MECHANICAL ENGINEERING for February, 1919, p. 155). Helium, however, was not used in the recent trip of the R-34 from East Fortune in Scotland to Roosevelt Field, Long Island.

This performance would have been impossible in the present year of grace without the feverish work done in the research laboratories of the allied countries under the stress of the past struggle, and in that way represents the fruition of that work. It also opens up great vistas of new possibilities for the utilization of lighter-than-air machines and for the application of the great inventions in that field of engineering made in this country as well as abroad.

Important Federal Commission

It having been made clear to President Wilson that the electric railways of this country are in a very bad way with respect to their finances, he appointed a commission called the Federal Electric Railway Commission, to investigate and report. This commission consists of

CHARLES E. ELMQUIST, President and General Solicitor of the National Association of Railway and Utilities Commissioners; formerly chairman of the Minnesota Railroad and Warehouse Commission.

EDWIN F. SWEET, Assistant Secretary, U. S. Department of Commerce, formerly Mayor of Grand Rapids, Michigan.

EUGENE MEYER, JR., Managing Director of the War Finance Corporation, by profession a banker. During his absence in Europe Lewis B. Wehle, counsel of the War Finance Corporation, will serve in his stead.

ROYAL MEEKER, Statistician, U. S. Department of Labor.

GEORGE L. BAKER, Mayor of Portland, Oregon, and chairman of the Organization Committee of the American Cities League of Mayors.

CHARLES W. BEALL, Nominated by the Investment Bankers' Association, member of the firm of Harris, Forbes & Company, investment bankers of New York City.

W. D. MAHON, President of the Amalgamated Association of Street and Electric Railway Employees.

P. H. GADSDEN, Chairman of the American Electric Railway Association's Committee on Readjustment and of its Committee on National Affairs, formerly chairman of the Association's War Board; Vice-President of the United Gas Improvement Company and president of the Charleston Consolidated Railway & Lighting Co.

The American Electric Railway Association has appointed a committee of 100 prominent business men engaged in a great variety of businesses. The chairman of this committee is Mr. Guy E. Tripp, of the Westinghouse Electric & Mfg. Co., New York City. Experienced men from all over the country are being called before the commission to testify. There is now the opportunity for doing great good in the country by putting forth unbiased information which will enable the utilities and the people to come to common grounds of understanding.

Considering the fact that a large number of electric railways have either gone out of business or into receivers' hands, and that vast amounts of capital are jeopardized, and that the great public dependent upon street railways for their daily journeys to and from their business are thereby seriously inconvenienced, it is truly an *important* federal commission. If its work be done well, as it is sure to be, and the public profits thereby, much will have been accomplished toward dispelling the prevailing ignorance concerning this important utility and public utilities generally.

This Commission has no power except to report and recommend —that is, it cannot enforce its decisions. It is appointed as a war-time measure and its members serve without compensation. Thus it may go out of existence at the time when expenditures for war cease.

The urgency of the situation is such that the Commission feels it cannot take time to investigate the different methods of valuing properties; that its main function will have been performed when it suggests remedies which will meet the immediate needs of the electric railways in order that they can continue to exist and give service to the public.—M. E. C.

Coöperative Course in Electrical Engineering

The coöperative course in electrical engineering which was established previous to the war under the joint supervision of the Massachusetts Institute of Technology and the General Electric Company, but was discontinued because of the S. A. T. C. courses, is now to be resumed.

The course covers a period of five years, of which the first two are identical with the old and well-established course in electrical engineering at the Institute, and the last three are divided between instruction at the Institute in Cambridge and experience associated with instruction at the West Lynn and other works of the General Electric Company. The work of the final year of the course is of advanced nature, with emphasis laid on the problems of administration, the design and development of engineering projects, etc.

While students are at work at the General Electric Company they receive regular compensation but are under supervision of teachers and their work in the shops is supplemented by conferences with works department heads in which technical and administrative problems arising at the works are discussed.

Distinguished Service Cross Awarded

It is with pleasure that we give below an announcement regarding one of our junior members which has been received from France:

Capt. Horace L. Smith, Jr., First Engineers, distinguished himself by extraordinary heroism in connection with military operations against an armed enemy of the United States at Charpentry, France, on October 4, 1918, and in recognition of his gallant conduct I have awarded him in the name of the President the distinguished service cross.

Awarded on December 17, 1918.

JOHN J. PERSHING,
Commander-in-Chief.

No. 2950.

This distinguished service cross citation is the culmination of many citations received by Captain Smith for valorous deeds rendered in the line of duty. Captain Smith is at present stationed near Coblenz, Germany.

Professor Lucke Honored

Prof. Charles E. Lucke, Mem.Am.Soc.M.E., and Head of the Department of Mechanical Engineering at Columbia University, has recently been honored by promotion to the rank of Commander in the United States Naval Reserve Forces. During the war Professor Lucke had the rank of lieutenant-commander and as head of the Gas Engine School at Columbia University directed the training of large numbers of men as engineering officers for submarine chasers and coast-patrol vessels. Professor Lucke's promotion was recommended by the Official Selection Board of the Navy and he is the first reserve officer to be honored with the rank. In announcing the promotion Franklin D. Roosevelt, Assistant Secretary of the Navy, also made it known that a special citation calls attention to Professor Lucke's "valuable assistance in training personnel to meet the great demands of the war."

Notes

President Cooley appeared before the Federal Electrical Railway Commission at Washington on Thursday, July 17, to give the results of his experience of 20 years in the valuation of public-utility properties, to the number of several hundred and aggregating in value well over one and one-quarter billions. Comment on the important bearing of the Commission's work will be found in another column.

On the afternoon of June 20 a sudden storm in the vicinity of New York so completely obliterated the sun's rays that there was an unprecedented condition of darkness, equal to that of the blackest night. According to the *Electrical World*, the demand upon the New York Edison Company was the greatest in its history, increasing in a very short space of time from 250,000 hp. to 425,000 hp. In spite of the suddenness and magnitude of this change, every part of the system met the exigency without failure.

ENGINEERING COUNCIL

Engineering Council[1] is an Organization of National Technical Societies of America, Created to Consider Matters of Common Concern to Engineers, as Well as Those of Public Welfare in Which the Profession is Interested

NATIONAL SERVICE COMMITTEE

Contributed by the Washington Office[2]

Department of Public Works

AS a result of a conference held at Chicago, April 23 to 25, and attended by the representatives of over seventy engineering organizations (see MECHANICAL ENGINEERING for June, p. 557, and July, p. 633), there has been introduced in each House of Congress a bill which proposes far-reaching changes in the executive machinery of the Federal Government. The new bill creates a Department of Public Works which will replace the Department of the Interior and will assemble under one head all engineering activities of the Government.

Such bureaus of the Interior Department as are non-engineering in character are to be placed under the jurisdiction of existing appropriate departments. The bill proposes that the Patent Office be removed from the Interior Department and placed under the Department of Commerce. The Bureau of Pensions is assigned to the Department of the Treasury. The Bureau of Education goes to the Labor Department. The Bureau of Indian Affairs is also transferred to the Department of Labor, but with the proviso that the engineering and construction work of the land and mineral surveys now performed under the direction of the Bureau of Indian Affairs are to be prosecuted under the Department of Public Works.

The new Department will also absorb the Supervising Architect's Office of the Treasury Department; the Construction Division, River and Harbor Improvements, Mississippi River Commission, and California Débris Commission of the War Department; the Bureau of Standards and the Coast and Geodetic Survey of the Department of Commerce; and the Bureau of Public Roads and the Forest Service of the Department of Agriculture.

The bill further provides that the Secretary of Public Works "shall by training and experience be qualified to administer the affairs of the Department and to evaluate the technical principles of operations involved in the work thereof." The measure, however, excepts from the foregoing provision the Cabinet officer who is at the head of the Department at the time of the passage of the bill.

Four assistant secretaries, each to be paid $7500 per annum, are provided and their duties outlined. One is to have administrative jurisdiction over all matters of engineering design and construction; another is to have charge of architectural design and construction; the third is to have jurisdiction over all scientific work and surveys, while the fourth is to be in immediate charge of all land and legal matters. The assistant secretaries are charged with the duty of coördinating and bringing into efficient relationship all the activities of the department so that it may be harmoniously and efficiently administered.

An important feature of the bill is the proviso that engineer officers of the U. S. Army detailed on non-military work are to be assigned by the Secretary of War to like duties under the new department, but for not over two years. This enables the Secretary of Public Works to make a gradual transfer of improvements and instrumentalities to civil administration without detriment to the public interest. Members of the Corps of Engineers may therefore, under the direction of the Secretary of Public Works, be detailed by the Secretary of War to temporary duty in the new department for such instruction, training and experience as is desired.

[1] Officers of Engineering Council: J. Parke Channing, *Chairman;* Alfred D. Flinn, *Secretary,* Engineering Societies Building, 29 West 39th Street, New York.

[2] Washington Office in charge of M. O. Leighton, *Chairman,* National Service Committee, McLachlen Building, 10th and G Streets.

Water-Power Legislation

A bill to create a Federal Power Commission composed of the Secretary of War, the Secretary of the Interior, and the Secretary of Agriculture, has been passed by the House and is now awaiting action by the Senate. Since the water-power question was the subject of exhaustive hearings at the last session of Congress, the committee which reported the bill decided that no further hearings would be held. The bill is accordingly substantially the same as those previously introduced and provides for the improvement of navigation, the development of water power and the use of land. The necessity for the legislation embodied in this bill is felt in all parts of the country and especially by those engineers who are intimately connected with the projects which it will affect. The bill should therefore have the close attention and active support of every engineer. Copies of the bill will be mailed upon request made to the Washington office of the National Service Committee.

Patents Legislation

Important hearings started before the House Patent Committee on July 9, preliminary to reporting bills which propose to remove the Patent Office from the jurisdiction of the Department of the Interior and to establish a United States Court of Patent Appeals. Another bill being considered proposes increased compensation and a larger force of employees for the Patent Office.

The former bills were drafted by and have the backing of the National Research Society which has been making extensive surveys of several Government Departments during the past year. It is the purpose of the National Research Society to provide for carrying out many proposed plans to encourage inventors by making the Patent Office an independent organization.

The Patent Office is one of the few Governmental agencies which is self-sustaining. Last year saw the first deficit since this office was established in 1837. The office carries a surplus of $8,150,464.

Other minor changes are proposed by the bills, such as decrease in patent fees and the manner in which they are paid, as well as restrictions upon patent attoneys. Testimony already taken before the committee indicates that the employees of the Patent Office are greatly underpaid and that comparative inefficiency has resulted because of loss of personnel.

Appropriation for Topographic Mapping

Although Engineering Council urged the importance of increasing the Government appropriation for topographic mapping from $300,000 to $500,000, this important item was reduced to $289,000 by the House, increased to $425,000 in the Senate, and finally approved for $325,000 by the House conferees. It is understood, however, that an additional $100,000 may be obtained from the Army's topographic appropriation.

Engineering Council interested itself in having this appropriation increased because of the value of complete topographic maps to the engineering profession. It was estimated that $500,000 would enable the Geological Survey to complete the topographic-map program in twelve and a half years. It is now hoped to get the remaining appropriation necessary through as an urgent deficiency appropriation.

Army Equipment for Highway Work

In addition to the 20,000 motor trucks which were recently turned over to the Bureau of Public Roads by the War Department, arrangements are now being made to distribute among the

states a large quantity of additional engineering equipment. This equipment will be distributed without charge and in accordance with recent legislation, empowering the Secretary of War to provide the States with military equipment not needed for military purposes but valuable in highway construction work.

The additional equipment will be returned from France as soon as possible. It includes about 1500 caterpillar tractors; about 400 road rollers, steam and gas-driven; and a large number of concrete mixers, road graders, elevating graders, rock crushers, industrial locomotives, industrial-railway track, dump cars, steam shovels, hoisting engines, electric motors, and quantities of smaller equipment. In urging the immediate return of this equipment, the Secretary of Agriculture called attention to the fact that the road program was the largest scheme now being developed for the improvement of the country, for the use of materials that will help stabilize business along a number of lines, and for the employment of labor.

Air-Service Development Problems

Despite the fact that Congress failed to appropriate what many considered a sufficient amount for the development of the U. S. Air Service, the Equipment Section of the Engineering Division is nevertheless anxious for inventors and designers to lend their assistance in the development of various airplane improvements and devices. The following equipment is suggested as being of particular value and accordingly well worth development:

Gasoline Tanks. A tank is desired which will withstand a salvo of 30-caliber ammunition, equally mixed, service, tracer, incendiary and armor-piercing bullets, fired at a range of 30 yd. and at the most vulnerable angle. There are to be 10 consecutive tests on as many tanks without fire occurring. The weight should be kept as low as possible, the maximum limit being 75 per cent more than for standard tank weights.

Air-Bag Floats, Landing Skids, Etc. The object of these devices is to prevent the machine from capsizing when landing in water and to keep the machine afloat after landing. Such devices should present as small an amount of wind-resistance surface as possible, should be light and readily detachable.

Mobile Independent Cranking Device. This should be mounted on a small auto truck. The cranking device should be electrically driven and arranged so that it can be backed up to the front end of any aeroplane and attached to the propeller with a flexible arm. The electric motor is then used to crank the engine, causing it to begin firing. When the engine picks up, the device should be automatically thrown out of connection with the propeller.

Gasoline Supply Gage. This gage should be responsive, serviceable, and accurate to the last half-gallon. It may be mounted on the tank, although it preferably should be mounted on the dashboard. This gage of course must register under conditions existing in aeroplane service when the center line of the tank changes rapidly to practically every possible plane, and is often 180 deg. out of its normal position for short intervals.

Portable Hangars for Field Service. At present canvas hangars do not weather winds or rainstorms well enough to be practical and they are generally too small. The improved hangar should be capable of housing four De Haviland planes with working space. They should provide for the necessary electric lighting and small machine work.

Campaign for Uniform Traffic Regulations

The Council of National Defense, through its Highways Transport Committee, is inaugurating a nation-wide campaign for the purpose of bringing about the adoption so far as possible of suggested uniform traffic regulations and directions. An alarming number of accidents occur daily on the highways and it is the belief of the Committee that through this movement life and limb may be conserved and results of an impressive character attained.

These suggested regulations and directions represent, the Council of National Defense believe, the best and most disinterested thought on the subject of highway accidents, and their cause and remedies, possible to be had. Prepared originally by Mr. William P. Eno, an authority on traffic, these regulations and directions have since been submitted for constructive criticisms to secretaries of state, state highway commissioners, the American Automobile Association, the National Automobile Chamber of Commerce, the Highway Industries Association, the National Highway Traffic Association and to scores of individuals competent to pass upon this question.

The Council of National Defense will be glad to give the public the benefit of lessons learned in this campaign, which affects every city and village throughout the country, and inquiries as to the progress of the campaign should be addressed to the Highways Transport Committee.

Coal for Foreign Shipment

An interesting condition has arisen in the position of the American coal producers in what may be called a world trade. On the one hand, the coal producers, through their various organizations, have expressed considerable dissatisfaction in the progress made in getting export coal trade under way. They regard the methods thus far devised as not promising. There is dissatisfaction arising from the rates which the Shipping Board will charge, and fear is expressed that American exporters will be unable to compete with English rates which are so much lower.

On the other hand, the Navy has found it necessary to take special steps to provide for an adequate supply of satisfactory coal for its use on vessels engaged in the return of troops and to carry out Navy orders. Under a recent issue of proposals soliciting bids for the furnishing of steaming coal after July 1, definite offers were received for only about one-half the quantity requested, some of the operators offering only a meager supply and some failing to submit bids. This is only partly due to the stringent Navy specifications.

It is therefore clear that this country cannot successfully compete in foreign markets if it cannot supply its own Navy. Apparently there is no question but that considerable business can be done under existing conditions in Europe with Northern Europe and the Mediterranean ports. Many, however, express the idea that there is little hope of establishing permanent markets there, but there is obviously a good opportunity to take advantage of the present situation by rushing quantities of coal to those markets at very respectable profits. Besides, our coal producers would benefit from the experience. Permanent and fertile fields for this product probably can best be found in Latin America and Canada.

It is now apparent that it is an economic necessity for the country to do an export coal business, but the restrictions of the Shipping Board's high rates, a decided timidity on the part of the Government to assist, together with the fact that on the face of things our coal men are not caring for the home market, the way that such export trade is to be accomplished is not clear. Nevertheless there is concentrated effort being put forth in Washington to reduce the formidableness of the obstacles which confront coal exportation and it now seems probable that a working plan will be hit upon.

National Conference on Commercial Engineering

There was recently held at Washington, D. C., a very important conference composed of administrative professors in engineering and commerce and representatives of several national engineering and educational societies. The purpose of the conference was primarily to direct public attention to the positive need in our country for an increasing supply of well-trained young engineers to enter upon business careers in the direction of industrial and commercial management.

Dr. Glen L. Swiggett, of the Bureau of Education, Department of the Interior, was chairman of the conference, and the A. S. M. E. was officially represented by Dean R. L. Sackett, of the School of Engineering, Pennsylvania State College. The conference served largely as a clearing house for the exchange of ideas leading to common thinking and action in respect to the program of the conference, and to the end that these might be placed on record the following resolutions were passed as representing the sense of the conference:

1 Industrial and commercial development has created a demand for men with technical engineering training and business ability. Manufacturing industries are seeking engineers qualified to serve in capacities requiring sound business training. Banks and brokers also need men with business training and the engineering point of view.

This need is rapidly increasing and bids fair to demand a large number of technically trained men for both domestic and foreign commerce.

2 In order to meet this demand the economic phases of engineering subjects should be emphasized wherever possible in engineering instruction. This may be done by emphasizing the problems of values and costs in the regular technical work and by introducing or extending courses in general economics, cost accounting, business organization and business law into the engineering curricula. These courses should be designed particularly to meet the needs of the engineering student.

3 The engineering phases of economic subjects should be emphasized wherever possible in commercial instruction. Students in commercial courses should also be given opportunity to take special courses in the basic principles and practices of engineering so that they may understand in general terms the operation of power plants and transportation systems from the engineering point of view.

4 It is also urged upon all institutions with departments in engineering and economics or commerce that they consider some plan of coördination to develop a course in preparation for those careers wherein practical training in modern languages, in the essentials of engineering and business theory and practice have been found to be both helpful and necessary.

Government Activities in Engineering

The National Service Committee through its Washington office is in immediate touch with governmental affairs affecting the engineering profession in general. These are naturally of a numerous and varied nature, and it is therefore impossible to cover them all in detail, but MECHANICAL ENGINEERING strives to give information regarding those which it deems of special interest and value. There may be, however, certain affairs of interest to some which we have failed to present, and on these the Washington office of the National Service Committee will gladly supply information. At the present time full and up-to-date particulars may be obtained on the following subjects:

Shipping Board's Reports and Addresses. Summer positions for college men; specifications for new ships; proportion of world's shipping; proposed plans for next fiscal year.

Road Construction Work. Latest state status; national appropriation bills; war material available; comparative U. S. and foreign program; committee arrangements for coöperation.

War Department. Contract-settlement regulations and operations; statistics series; equipment and realty advertised for sale.

Mining. Plans for completing and executing findings of War Minerals Relief Commission; Safety Engineer and Accident Statistics, by A. H. Fay, of Bureau of Mines; proposed plans to protect war minerals, potash, etc., by license and duty; detailed report of Geological Survey on shipments of coal and coke.

Railroad Administration. Latest operating and financial statements; movement of traffic in various regions.

New Sundry Civil Appropriation. Government departments and bureaus; reports for current year, etc.

Purchase of Airplanes or Motors. The Salvage and Sales Branch of the Air Service, 6th and B Streets, N. W. Washington, D. C., announce that those persons who contemplate purchasing a Government airplane or motor, should list their names in the above office, so that they may be advised when the opportunity arrives for them to make a purchase. Detailed information of equipment proposed for sale and method of sale can be obtained from the Salvage and Sales Branch.

Oil Lands in Utah. Reports from the Geological Survey, Department of the Interior, indicate that although considerable drilling has been done in the state of Utah, no oil has been produced in commercial quantities. Sandstone saturated with asphalt and other hydrocarbon compounds and small showings of oil in wells at several places suggest that oil may be found in commercial quantities where the rocks are favorable for oil accumulation.

Mineral Deposits in the United States. The United States Geological Survey recently published Bulletin 690, which contains those papers dealing with zinc and copper ores at Ophir, Utah; gravel deposits in Arkansas, with special reference to their possible utilization as a source of hard pebbles for grinding mills; phosphate deposits in the Uinta Mountains, Utah; quicksilver deposits in the Phoenix Mountains, Ariz.; and manganese deposits near Butte and in Madison County, Mont. This bulletin is completely descriptive and contains important illustrations and maps.

Outline Map of the United States. The Coast and Geodetic Survey, Department of Commerce, recently completed a new outline map of the United States on the Lambert Conformal Conic Projection, scale 1-5,000,000, dimensions, 25 in. by 39 in. This map is intended merely as a base to which may be added any kind of special information desired. The shoreline is compiled from the most recent Coast and Geodetic Survey charts. State names and boundaries, principal rivers, capitals and largest cities in the different states, are the only information otherwise embodied. This map is based on the same system of projection as that of the armies of the allied forces in the military operations in France. It is being used extensively by the Army and will probably be of interest and value to engineers.

NATIONAL RESEARCH COUNCIL

DIVISION OF ENGINEERING [1]

DR. HENRY M. HOWE, Chairman of the Division of Engineering of the National Research Council, who has been serving for the past three months as Scientific Attaché to the American Embassy at Paris recently returned to New York. Time has not as yet permitted Dr. Howe to prepare a report of his work during his stay in Paris and at present details are accordingly lacking. Research abroad, however, is receiving considerable attention and plans are now being made whereby the United States may be properly acquainted with and assist in the extension of international research.

The work of the Division of Engineering in this country is progressing along many lines and recent tentative reports are now available in connection with the work of three important committees. These are briefly presented herewith.

Committee on Improvement of Metals at Blue Heat. A meeting of this committee was recently held at the new offices of the Division of Engineering at 29 West Thirty-Ninth Street, New York City. The committee has been engaged for some time past in a study of the behavior of high-speed steel when at temperatures below the critical point, and since it proposes to confine itself in the future to problems associated almost entirely with steel, the committee requested that it hereafter be known as the Committee on Physical Changes in Iron and Steel. The personnel of this committee is as follows: Zay Jeffries, Chairman, R. R. Abbott, G. H. Clevenger, J. V. Emmons, F. B. Foley, H. J. French, A. H. Miller and Albert Sauveur.

Committee on Fatigue Phenomena of Metals. This committee was created in August, 1918, for the purpose of investigating problems arising in connection with the electric welding of ships and the failures of aireraft. Prof. H. F. Moore, of the University of Illinois, is chairman of the committee and at a meeting held at Atlantic City on June 27, plans were made for an elaborate and intensive study of the problems lying within the committee's field.

Committee on Neumann Bands. This committee was formed as a result of testimony given in connection with the investigation of the molasses tank disaster at Boston. An expert stated that it was his opinion, based upon the number and formation of the Neumann bands, that the speed of impact which caused the breakage was not over 15 ft. per sec., and if the primary break was located as was claimed then the results disprove the theory of an explosion, for in such case the speed of impact would have reached well into the hundreds of feet per second and the formation of the Neumann bands would have been entirely different. This implied relationship between speeds of impact and Neumann bands was hitherto unknown to exist but upon having its attention called to the fact the Division of Engineering immediately appointed a committee to investigate the entire field. The chairman of the committee is Prof. Charles E. Munroe and although some work has been done the relationship as expressed above has not as yet been determined.

[1] Dr. H. M. Howe, *Chairman*; G. H. Clevenger, *Vice-Chairman*, Engineering Societies Building, 29 West 39th Street, New York.

NEWS OF THE ENGINEERING SOCIETIES

Reports of Annual Conventions of American Railroad Association, American Water Works Association, American Society of Civil Engineers, American Institute of Electrical Engineers, etc.

American Railroad Association

That fifty out of the three hundred exhibits shown on Young's Million Dollar Pier, Atlantic City, at the convention of the American Railroad Association held on June 18 to 25, were of machine tools, indicates how close is the relation between the machine-tool industry and the builders of railway equipment. Many of the machine tools on exhibition were new models and a casual study of their design indicates a tendency toward greater weight, making for rigidity and greater production. In the course of the numerous official sessions considerable time was given to the discussion of reports on many subjects pertaining to car and locomotive design and maintenance. Among these were such subjects as car wheels, couplers, draft gears, car trucks, tank cars, mechanical stokers, locomotive headlights, superheater locomotives and design, maintenance and operation of electric rolling stock.

American Water Works Association

A notable feature of the thirty-ninth annual convention of the American Water Works Association, held in Buffalo on June 9 to 13, was a paper describing a new and unique reciprocating pumping engine which incorporates the uniflow principle in the operation of the pump. The engine is of the horizontal extended type having one steam cylinder and one double-acting plunger pump. Its normal working water pressure is 100 lb. per sq. in.; the suction lift is approximately 15 lb. plus the friction in about 60 ft. of suction pipe. This engine will operate in the Porter Ave. water-works pumping station of the City of Buffalo. It is anticipated that the tests will show a duty of 180,000,000 ft-lb. per 1000 lb. of steam.

The report of the Committee on Private Fire Protection Service reviewed the various physical and financial questions involved and made specific recommendations as to each. Much hearty commendation of the report followed its reading. It was voted to continue the committee instead of adopting the report and discharging the committee as it recommended.

A progress report of the American Committee on Electrolysis stated that a technical sub-committee had been created and a plan had been formulated under which experts would be engaged to study electrolysis.

National Gas Engine Association

Plans for increasing the activities of the National Gas Engine Association were laid at the twelfth annual meeting of the Association held on June 2 and 3 in Chicago. The reason for reorganizing the Association, as expressed by President O. H. Fischer, was the necessity for developing a greater coöperation between the manufacturers of internal-combustion engines in order to cope with the present situation, particularly in regard to labor conditions. Various aspects of the labor question were treated by Chris Heer in a paper entitled The Industrial Committee, Its Work and Future. Complete organization of the employer and employees of each industry affiliating with national organizations, coöperating and working in conjunction for the best interests of all, he believed, would come nearer solving and taking care of the labor question than any other method.

I. R. Todd, in a paper on Reconstruction Problems, took a most hopeful and optimistic view of the future awaiting American industry. With the balance of trade in our favor, with our growing merchant marine and our recent legislation permitting American bankers to establish foreign branches, American business men to coöperate for foreign trade, and authorizing the War Finance Corporation to extend credit to the extent of one billion dollars to promote this trade, he said, one cannot contemplate present conditions without anticipating a great future for American business.

Another paper of interest was an account of early pioneering days in the gas-engine field, by George Cormack.

American Concrete Institute

Many of the papers presented at the annual meeting of the American Concrete Institute, which was held on June 27 and 28 in Atlantic City, N. J., were devoted to the work of the Emergency Fleet Corporation. During the war the Concrete Ship Section, Emergency Fleet Corporation, developed a special light-weight aggregate for concrete, thereby obtaining a concrete of considerable strength weighing only 99 lb. per cu. ft. The possibilities of using such light concrete in building construction were discussed by A. W. Stephens in a paper entitled Economic Possibilities of Light-Weight Aggregate in Building Construction. The data and allowable costs per cubic yard in this paper would permit the higher-priced but lighter aggregate to compete with trap rock and gravel.

The report of the Committee on Standard Building Regulations for the Use of Reinforced Concrete contained the following clause:

> Cinders shall not be used as coarse aggregate in concrete for reinforced-concrete structures without tests acceptable to the Building Department showing the strength of such concrete. Cinder concrete may be used for fireproofing, for floor and roof slabs, not exceeding 8-ft. span, and for partitions. Where cinders are used as the coarse aggregate they shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

This regulation brought out considerable comment. Ira H. Woolson, who has had much experience with cinder concrete, went on record to the effect that, in his opinion, 15 per cent of unburned coal was not detrimental and might be permitted in anthracite cinders, and that a small percentage of ashes could also be allowed without bad effects in the resultant concrete. The matter will be considered further by the committee in the light of the discussion.

American Society of Civil Engineers

The annual convention of the American Society of Civil Engineers was held in Minneapolis on June 17. The main topic of the business session was the report of the Development Committee, which included recommendations in regard to internal relations and local associations, technical activities and public service, and relations with other societies. It was the opinion of the committee that the identity of the four national societies known as the Founder Societies should be preserved, but they added that the time had now come when the society should adopt the principle of becoming an active national force in economic, industrial and civic affairs. To do this effectively they recommend that jointly with other engineering organizations a comprehensive organization should be formed embracing (1) the local affiliation of the branches of the national technical societies and the local technical societies, (2) a state council composed of representatives from the local affiliations, and (3) a national council consisting of representatives of the national technical societies and from the state council or state group organizations. With respect to the internal relation of the society, the committee suggested the establishment of regulations intended to develop greater activities

among the local associations. The creation of committees of the parent society and local associations charged with the responsibility for promoting greater technical activity was advised by the committee. Recommendations were also made to prepare, in coöperation with other founder societies, a standard form of bill for the licensing or registration of engineers, to be used in the framing of legislation, and to maintain an agency in Washington, D. C., or elsewhere, for the purpose of keeping advised of all proposed Federal legislation and departmental rulings and regulations involving directly or indirectly questions of engineering.

Engineering Educators Meet in Baltimore

The lessons of the Great War in matters of education were discussed at the 27th annual meeting of the Society of the Promotion of Engineering Education, held at the Johns Hopkins University, Baltimore, Md., during the last week of June.

At the opening session, following an address of welcome by President Frank J. Goodnow, of Johns Hopkins University, and the response by Professor John F. Hayford, president of the society, the Special Committee on the Report of the Joint Committee on Engineering Education presented its preliminary report in the form of six specific resolutions based on Dr. Charles R. Mann's paper on The Study of Engineering Education, which was presented to the society at its last annual meeting. These resolutions prompted considerable discussion and comment. Two of the resolutions of general interest are quoted below:

Resolved. (1) That this Society, through its Committee on Admission, or otherwise, recommend that as a matter of experiment and research psychological "objective," "trade" or other similar tests be given to all students after admission to engineering courses of study and that the ratings thus obtained be compared with their subsequent scholastic progress.

(2) That the Society should coöperate with the national and other engineering societies, with a view to establishing a classification of the work, or positions, including specifications as to necessary preparation and qualifications, into which our engineering graduates enter, so that undergraduate students would thus have a clearer understanding of the work for which they are preparing themselves and instructors have before them a constant reminder of the main purpose of their teaching work.

The subject of psychological tests was further discussed in two papers. One, entitled Mental Tests for Engineering Students, was presented by Prof. C. L. Thurston, Division of Personnel and Psychology, Carnegie Institute of Technology, Pittsburgh, Pa., and the other, entitled Vocational Intelligence Examination to Fourth-Year M. E. Students, was read by Prof. William T. Magruder, of Ohio State University. Both of these papers were enthusiastically received.

The second session of the convention was devoted to a general discussion of the Effect of the War on Engineering Education. The discussion was opened by Dean Anson Marston of Iowa State College, and was participated in by many, including the following A. S. M. E. members: Profs. Carl C. Thomas and Alexander G. Christie, of the Johns Hopkins University; Prof. William T. Magruder, Dean A. A. Potter, Kansas State Agricultural College, and Prof. Dugald C. Jackson of the Massachusetts Institute of Technology. This theme was carried into a later session when Col. F. J. Morrow, Chairman of the War Department Committee on Education and Special Training, described the Government's plan for the continuation of the Reserve Officers' Training Corps. As part of the discussion of the topic set for this session, viz., Military Training in Engineering Schools, Major Harrison Tilghman from Fort Monroe told how the Coast Artillery was already putting its plans for the R. O. T. C. into operation.

During the convention a number of the standing committees of the society made their annual reports. Of special interest to the mechanical engineering profession are those of Committee No. 16, Mechanical Engineering Courses, Prof. Oscar A. Leutwiler (Mem. Am. Soc. M. E.), Chairman, and of Committee No. 20, Standardization of Technical Nomenclature, Prof. John R. Faig (Mem. Am. Soc. M. E.), Chairman.

At the final session held on Saturday morning, Arthur M. Greene, Jr., Mem. Am. Soc. M. E., Professor of Mechanical Engineering, Rensselaer Polytechnic Institute, and Chairman of the A. S. M. E. Committee on Research, was elected president for the ensuing year, and Dean A. A. Potter, vice-president. Following the election Dr. Ira N. Hollis, Past-Pres. Am. Soc. M. E., President of Worcester Polytechnic Institute, read a paper on Engineering Colleges and Their Administration.

The social features of the convention included an annual-mixer meeting and the annual dinner, both held at the Baltimore Country Club, an informal smoker and round table discussion, and a half-day excursion to the United States Naval Academy and the Engineering Experiment Station.

C. B. LE P.

American Institute of Electrical Engineers

The program of the annual convention of the American Institute of Electrical Engineers, held at Lake Placid Club, N. Y., June 24 to 27, provided an even balancing of the business and entertainment features, and this innovation met with general approval. Of special interest were the three sessions held under the auspices of the Institute's Development Committee. The report presented by this committee, which was based on suggestions forwarded to its members by the local sections and by individual members, outlined a plan for the improvement and development of the Institute's activities. Among the recommendations proposed were the following:

1 Development of the scope of the monthly Proceedings in order to include, in addition to the high-grade electrical engineering papers which have formed the principal part of the publication up to the present time, other material of more general interest, without in any way lowering the Institute's standards.

2 Inclusion in the monthly publication of a set of abstracts of practically all papers presented at section meetings throughout the country.

3 Consideration of whether or not a satisfactory plan can be developed which will eliminate the present wasteful practice of printing practically all papers twice, once in the monthly Proceedings and again in the annual Transactions, by possibly printing the monthly in two sections, bound together in one publication when issued and so arranged that they may be separated later by the recipient, who may wish to dispense with the transient matter and retain the part containing technical matters and discussions of permanent value.

4 As a result of the improvement of the monthly publication, it will become a better advertising medium; and it is suggested that advantage be taken of this fact to develop the advertising section and thereby meet the additional cost of enlarging the editorial staff and printing more material.

5 Create a New York Section, organized and conducted along the same lines as existing sections elsewhere.

6 Extend the present practice of holding some of the Institute and Directors' meetings in different parts of the country where local sections are established, instead of holding nearly all of these meetings in New York as at present.

7 Divide the country into geographical divisions corresponding in number with the number of Institute vice-presidents; and select one vice-president from each of these districts.

8 Make it a part of the duty of each vice-president to visit the sections in his own division at least once a year.

9 Pay the traveling and living expenses of the officers and board members attending Institute meetings.

10 Increase the vice-presidents' term of office from one year to two years. Provide that no member of the Board of Directors may continuously hold office for more than six years.

11 Decentralize committee work as far as may be found feasible and desirable, by substituting section committees for some of the Institute committees. Appoint a general committee to study this question and to make recommendations.

12. Present more high-grade papers of general engineering interest.

13 Create a committee in each section charged with the duty of assigning to the younger members specific participation in designated meetings by the preparation of papers and discussions, or otherwise. By this and other methods, including appointment of a reasonable number of the younger men to membership on committees, it is hoped to stimulate the interest of the younger members and thereby increase their loyalty to the organization and their opportunity for self development.

All of these recommendations were approved in principle, with the understanding that details would be worked out by appropriate committees.

In his presidential address, Comfort A. Adams emphasized the

great need of closer coöperation in commercial, industrial and scientific transactions. After delivering his address President Adams introduced President-Elect Calvert Townley, who in a brief address called attention to the tremendous work the engineer had done during the war, and added that the possibilities for the engineer making a prosperous period of peace were many times greater.

The Power Station Committee announced that it would shortly present to the Institute the results of its labors for the last two years on Limits of Speed and Power of Single-Shaft Steam Turbo-Generator Units.

In the report of the Instruments and Measurements Committee reference was made to the effect of the war on the development of the manufacture of thermoelectric couples in this country. Thermoelectric couples of American manufacture, the report indicated, "are superior in every way [to those of German manufacture] and are now available for the accurate measurement of alternating current of any frequency. Their sensibility is such that a current of one milliampere will produce a deflection of three millivolts in a direct-current voltmeter."

"The increase in the use of electrical energy in the iron and steel industry in the last few years," according to the report of the Iron and Steel Industry Committee, "has been remarkable and partly responsible for the prominent position the United States has taken in furnishing steel products to the entire world. Over 500 motor equipments are in use in this country, driving main rolls with a maximum horsepower of over 850,000, while the total horsepower of auxiliary motors exceeds 1,350,000, making a total of 2,200,000 hp. which requires about 650,000 kw. in generator capacity. In addition, electric furnaces require approximately 250,000 kw. in generator capacity, or a grand total of 900,000 kw. generator capacity in the iron and steel industry. This is by far the largest amount of electric energy required in any one industry, and from all indications will continue to increase considerably in the future."

American Society for Testing Materials

Of special interest is the action on phosphorus and sulphur limits in various specifications covering steel products taken by the American Society for Testing Materials at their 1919 meeting held in Atlantic City, N. J., June 24-27. Last year, by suggestion of the Committee on War-Emergency, the society introduced in the specifications for finished steels what is known as the phosphorus and sulphur note. This note read as follows:

> In view of the abnormal difficulty in obtaining materials in time of war, the rejection limits for sulphur in all steels and for phosphorus in acid steels shall be raised 0.01 per cent above the values given in these specifications. This shall be effective during the period of the war and until otherwise ordered by the society.

It has now been decided to restore the normal figures at once for those steels in which quality is most essentially affected by the change, and to retain the war clause in the other specifications until next year. This action may be summarized as follows:

War Clause Removed 1919:	War Clause Retained for Present:
Bridge steel	Building steel
Structural nickel steel	Ship steel
Plates for stationary boilers	Carbon-steel rails
Forgings and steel for forgings	Tie plates
Splice bars, except low-carbon	Splice bars, low-carbon
Track bolts, except low-carbon	Track bolts, low-carbon
Wheels and tires (railway), all	Plates for locomotives and cars
Spring steels, all	Tubes for locomotive and stationary boilers
Tool steel	Chain
Automobile steels	Bars for concrete reinforcement
Girder and high tee rails	Castings.
Screw stock.	

A new tentative specification for plates for forge welding, which was adopted upon recommendation of Committee A-1 on steel, limits carbon to a maximum of 0.18 per cent, phosphorus to 0.04 per cent, and sulphur to 0.05 per cent. The manganese range is 0.30 to 0.60 per cent. The minimum tensile strength for plates ¾ in. or under is 48,000 lb. per sq. in., and for plates over ¾ in., 45,000 lb. per sq. in. The yield point is put at one-half the tensile strength. Modifications in elongation are made in proportion to thickness.

The results obtained from an experimental study of the effect of heat treatment on fatigue-resisting strength of nickel steel and chrome-nickel steel were presented by H. F. Moore and Arthur G. Gehrig. The nickel steel was of about 3.3 per cent nickel content and the chrome-nickel steel contained about 0.8 per cent chromium and 1.3 per cent nickel. The conclusion was reached from the performance of both static tension tests and tests under reversed bending stresses made with annealed, heat-treated, and polished specimens, that the results of a static tension test are not a reliable index of fatigue strength of a material under oft-repeated low stresses, and that high-stress, short-time fatigue tests do not give a reliable index of fatigue strength under oft-repeated low stresses. It was also established that a heat treatment may raise the elastic strength of a steel without increasing its fatigue resistance under low stresses, and that perfection of surface finish is an important factor in determining fatigue resistance under oft-repeated low stresses.

Five papers were presented in which magnetic analysis as a method of testing ferrous material for quality was discussed. The first, by C. W. Burrows and F. P. Fahy, described the methods used and the results of some measurements, emphasizing the very close relationship between the magnetic and the mechanical characteristics of steel. Various practical applications of magnetic methods were dealt with in three papers as follows: To the discovery of defects in steel rails, by P. H. Dudley; to the testing of ball-bearing races, by R. L. Sanford and M. F. Fischer; and to the location of flaws in rifle-barrel steel, by R. L. Sanford and W. B. Kouwenhoven. Finally, magnetic properties as affording a basis for determining microstructure were considered by C. Nussbaum.

Five new instruments and machines for testing were also described. T. D. Lynch and P. H. Brace, in a paper entitled Wire Testing Extensometer, explained the operation of this instrument. It grips the wire by a spring clamp at one end of a pair of distance bars, and at the other end of the bars by two small rollers which carry mirrors on their ends. These mirrors reflect a beam of light from a small collimation tube at one side of the instrument to a curved scale attached on the opposite side. Reading to 0.00002 in. is possible. A miniature Brinell machine for use in inspection of cartridge cases was described by S. L. Goodale and R. M. Banks in a paper entitled Development of Brinell Hardness Tests on Thin Brass Sheet. The impression is made by a 1/16-in. ball under a 15-kg. load. The design of a very compact repeated-stress machine for testing electrically welded ship plates was reported by F. M. Farmer in his paper on A Fatigue Testing Machine. The test piece is a rotating simple beam, loaded at the third-points, and the whole machine is only 5 in. by 19¼ in., though the specimen is 0.4 in. in diameter and 13 in. long. A new viscosimeter for gasoline, designed by W. H. Herschel, as described in his paper, A Viscosimeter for Gasoline, has an outflow tube 24 diameters in length instead of 7 as in the Engler and Saybolt instruments. An apparatus in which a slab of pitch is bent on a hinged plate while immersed in water, the temperature of which can be varied, was described by H. E. Lloyd and P. P. Sharples, in a paper on Apparatus for Determination of Breaking Point of Pitches.

There are now 620 known trade associations in the eastern half of the United States, of which 323, or over half, are located in New York City, 75 in Chicago, and the remaining 222 in smaller cities. The increase in the number of these associations has been rapid and their utility has been emphasized by the conditions of business and trade resulting from the war. A building is now being erected in New York, known as the National Association Building, on Forty-third Street, which it is expected will eventually become the headquarters of a large number of trade associations, thus bringing together many of the important business activities of the industries in the direction of interchange of data, unification of methods in specifications and accounting, direction of educational campaigns, etc.

REPORT OF THE COMMITTEE ON INDUSTRIAL RELATIONS

Appointed to Report Upon the Advisability of Establishing a Permanent Committee on the Relations Between Employer and Employee

THE following report of the Committee on Industrial Relations was presented at a meeting of the Council on February 22, 1919:

TO THE PRESIDENT AND COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS,

29 West 39th Street, New York City.

Gentlemen:

In compliance with your request, the special Committee appointed by the Council of the A. S. M. E. on December 6, 1918, to report upon:

a "The advisability of establishing a permanent committee on the relations between employer and employee; and

b The best method of encouraging our membership to fulfill their high duty in that field for which their training and activities should fit them,"

held a protracted session on Friday, January 17, 1919, in New York City. Aside from the undersigned Chairman, there were in attendance: John W. Lieb, Vice-President, New York Edison Co., New York City; W. H. Manss, Director War Service Executive Committee, Chamber of Commerce, U. S. A., Washington, D. C.; Henry D. Sharpe, Treasurer Brown & Sharpe Mfg. Co., Providence, R. I., and Magnus W. Alexander, Managing Director, National Industrial Conference Board, Boston, Mass.

At the outset the Committee discussed and agreed on the importance of a desirable coöperative relation between employer and employee as a fundamental and potent factor in the efficient conduct of industry and the proper discharge of social obligations resting upon both parties. The Committee, moreover, was unanimous in the opinion that a clear understanding of the employment relation and of correlated phases of industrial activity by all classes of the population is necessary for the development of sound and sane public opinion regarding these vital issues; and that the engineers of the country, both as primary factors in the country's industrial development and as intelligent citizens, must be enlisted on the task of correctly informing the public and properly shaping its opinion in respect to industrial questions.

The Committee, therefore, urges most strongly that adequate space be provided on programs of meetings of the Society and its branches in order that qualified speakers may keep the members of the Society in close touch with the latest developments in the human relationship in industry. Speakers should be chosen, however, who do not merely propagate a personal opinion but who can speak with the authority of deep knowledge of and long experience with the subject under discussion. They should, in engineering fashion, analyze the elements of a proposition, show its feasibility and, where possible, its practical application and resultant benefits so that justified deductions may be drawn from accumulated data and experience.

The Committee will be very glad to assist the Council and the Committee on Meetings of the Society in suggesting topics and speakers on the employment relation and allied subjects.

The Committee fully discussed the advisability of establishing in the Society a standing committee on relations between employer and employee, and unanimously agreed that it does not seem advisable at this time to recommend to the Council the appointment of such a committee. In this decision is involved a consideration of the Society's purposes and the character of its membership. We submit, therefore, the following observations:

In the language of the Society's Constitution, "The object of the Society is to promote the Arts and Sciences connected with Engineering and Mechanical Construction."

We believe that The American Society of Mechanical Engineers was created for the purpose of bringing together knowledge and experience in the scientific mechanical engineering field in order to help in the promotion of the Arts and Sciences of Engineering and Mechanical Construction and in the advancement of the status and prestige of mechanical engineers. In this scientific field, The American Society of Mechanical Engineers occupies a commanding and influential position and its achievements are a credit alike to the Society as a whole and to individual members who have been active in promoting the Society's legitimate ends.

Unlike the mechanical engineer, who deals with the ascertainment of scientific facts and with their application to the mechanical arts, the sociologist in industry, if we may use this term in contradistinction, endeavors equally to ascertain facts, but, supplementary to this, he also collects opinions and finally compromises between abstract judgment founded on facts and justified consideration of prevailing public opinion and social and political conditions. We believe that as an organization The American Society of Mechanical Engineers should steer a scientific rather than a sociological course and deal more largely with facts and experience rather than with opinions and expediency compromises.

In so far as the membership of the Society is concerned, it may be conveniently divided into those who are in active administrative charge of industrial enterprises, those who are devoting their energies to scientific engineering in private or public capacity, and those who constitute the group of teachers of engineering and general science. Only the men comprising the first group, aside from some individuals in the other two groups, would have practical knowledge of and intimate experience with the many complex and often perplexing questions involved in the employment relation. But these men are usually also members of national and local trade and civic organizations and of specially organized bodies, whose chief endeavor is devoted to the considerations of the employment relation and kindred subjects. As far as these latter activities are concerned, the men of the first-named group of the A. S. M. E. function, therefore, principally through such organizations.

Merely to establish in the Society a standing committee on relations between employer and employee without giving the committee the necessary authority and large financial resources to prosecute its investigations and formulate reports with the thoroughness and accuracy which they demand, would neither contribute materially to the solution of the many vexing problems involved in the situation nor hold the Society true to its established course. It would, moreover, project the Society into a field in which there are now effectively operating several organizations especially devoted to the study of economic and sociological problems in industry.

These organizations are constantly tapping the knowledge and experience of those members of The American Society of Mechanical Engineers who are engaged in executive and administrative functions in industry. A close connection between the Society and these organizations, therefore, already exists and can be made more effective by placing before the membership of the A. S. M. E., through papers and discussions as suggested, the progress made in the study and development of the so-called Labor Problem by those who are qualified for this task.

For these reasons the committee deems it inadvisable for the Society at present to enter the controversial field of industrial economics as involved in the relationship between employer and employee. Individual members of the Society should, however, be encouraged to join organizations especially studying the human relationship in industry, and the Society as a whole may properly seek, where it is practicable, to be represented on committees of such organizations; especially the National Industrial Conference Board and the War Service Committee organizations of the Chamber of Commerce of the United States.

Respectfully submitted,

(Signed) ANSON W. BURCHARD, *Chairman.*
JOHN W. LIEB,
W. H. MANSS,
HENRY D. SHARPE,
MAGNUS W. ALEXANDER.

American Machinery in Indo-China

The following has been received by the Secretary from W. H. Rastall, Trade Commissioner, Buitenzorg, Java:

Manufacturers interested in exporting machinery will find the present situation in Indo-China very interesting. Formerly practically all equipment was imported from France and the French policy was to retain this business where practicable. War conditions have made it difficult for France to supply this colony with the necessary equipment and as American ships are now running direct to Saigon, the buyers in Indo-China are beginning to send their inquiries to America. This is prompted by a spirit of friendliness as well as business convenience.

A certain amount of American equipment is being used with very satisfactory results. Also the performance of the United States in the war has advertised to the buyers of Indo-China American manufacturing ability and the general excellence of American machinery.

A further inducement operating in favor of American goods at this time is the rate of exchange as American dollars are very much cheaper in Saigon than they were formerly.

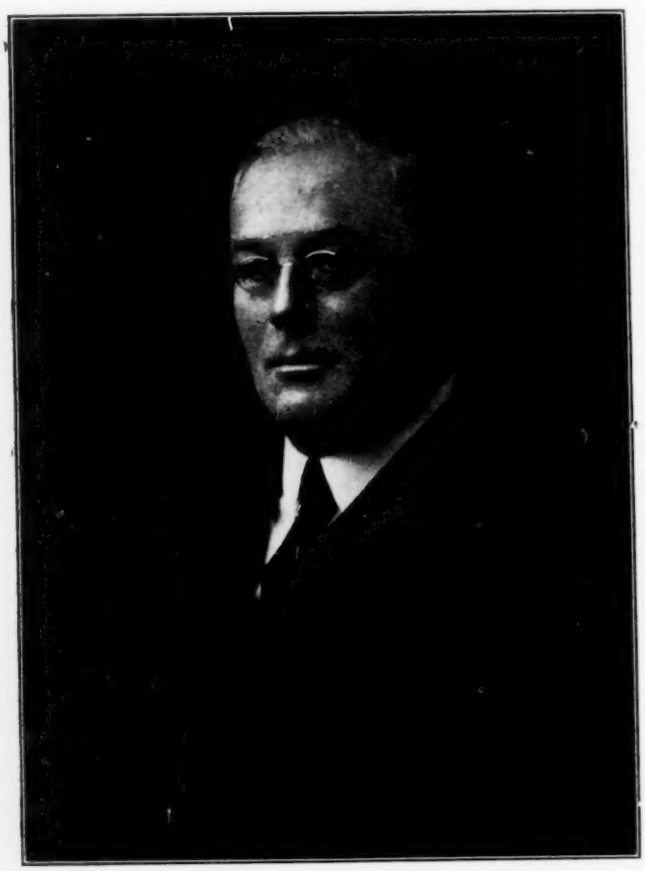
The market in Indo-China is not large but there is a certain demand for rice mills, mining machinery, road- and railroad-building equipment, automobiles and the miscellaneous equipment needed in all countries.

NECROLOGY

SAMUEL T. WELLMAN

Samuel T. Wellman, a past-president of the Society, and a pioneer in the world's steel industry, whom Charles Schwab once characterized as "the man who did more than any other living person in the development of steel", died suddenly from heart trouble on July 11, 1919, in Stratton, Me., while on his way to camp. His death came as a shock to his very large circle of friends, many of whom had only recently met him at the Spring Meeting of the A. S. M. E., at Detroit.

Mr. Wellman was born on February 5, 1847, in Wareham, Mass. At that time his father was superintendent of the Nashua Iron Co. of Nashua, N. H. He was educated in the schools of Nashua and in Norwich University, Norwich, Vt., where he spent



SAMUEL T. WELLMAN

one year in the engineering course. During the Civil War he served as a corporal in the First New Hampshire Heavy Artillery.

Perhaps the most interesting account of Mr. Wellman's entrance into and activities connected with the steel business is that given in a letter which he wrote to the Cleveland Engineering Society at the time of his election to honorary membership in that body. Mr. Wellman wrote:

> Perhaps the story of my leaving home at that time might be interesting. My father was superintendent of a small iron works among the hills of New Hampshire, which among other business included the rolling of steel locomotive tires which they made from hammered steel blooms imported from England. To properly heat these blooms, they had arranged with C. W. Siemens to build a regenerative gas furnace. The drawings were sent over and turned over to me, who had never seen a drawing of that kind before. My father asked me if I thought I could build the furnace and have it exactly like the drawings. After studying them over a little while, I told him that I thought I was equal to the task. He told me to get the furnace built at the earliest possible moment. I had just finished the furnace and had a drying-out fire in it when a big black-whiskered Englishman walked into the office and announced that he was the Siemens engineer who had been sent from England to build this particular furnace. My father turned him over to me to go out into the works and show him where the furnace was to be located, which I did, and my English friend was very much amazed to find the furnace all finished. He was pleased as well, and said, "Why, we have only to start the furnace now; you have made a proper job of building it." So everything else being ready, we started up the gas producers and the furnace and everything worked to perfection. The engineer was so pleased with what I had done that when he left he asked me to go with him to Pittsburgh as his assistant in the starting of a crucible-steel furnace which was finished and waiting for him to start. It is needless to say that I did not have to have a second invitation, but went to Pittsburgh with him. This was in 1867, and I spent over a year there. The first few months of that time were spent starting up and operating the first crucible-steel furnace built in America, at the works of Anderson, Cook & Co. To show what a tremendous saving this furnace was over the old coke-fired furnaces, I will only say that it melted a ton of steel with an average of 1000 lb. of nut coal which cost less than $1, while to melt a ton of steel in crucibles in the old-fashioned coke furnaces took three tons of the very best coke, costing anywhere from $2 to $10 per ton. This style of furnace was a great success and in a very few years had driven the coke furnace out of use.
>
> From Anderson, Cook & Co. I went to Singer, Nimick & Co's. works, where I built two crucible-steel melting furnaces of the same type as the one which I went to Pittsburgh to start. After that I spent some time in the office of the Siemens agents in Boston, and also at steel works in different parts of the country starting crucible steel furnaces of the same type. I then built a crucible-steel melting furnace at the Chrome Steel Works in Brooklyn, N. Y., which was a success. From there I went to the Bay State Iron Works, in South Boston, Mass. (I having separated myself from the agents of the Siemens furnace some time before this), where I built the first open-hearth furnace that was a commercial success in the United States. This was a pronounced success in a great many ways, making a quality of steel which up to that time had not been reached in this country. The principal use to which it was put at that time was in the manufacture of locomotive fireboxes. From there I went back to the old works in New Hampshire where my father was still superintendent, and built for them an open-hearth furnace, a plate-rolling and bar-rolling mill.
>
> I then came to Cleveland in 1873 to design and build the Otis Steel Works, with which I was connected as engineer and superintendent for 16 years. It is useless for me to say very much about the history of the Otis Steel Co., as it is too well known here. But there are two inventions which I worked out during the time I was connected with the Otis company that are today absolutely indespensable to the economic operation of any open-hearth steel works. I refer to the open hearth charging machine and the use of the electromagnet for handling pig iron and scrap steel. Just a few figures will give you a little idea of their importance to the trade and what they are saving every day.
>
> There were made in this country in 1916 approximately 39,000,000 tons of pig iron and about the same quantity of steel ingots of all kinds. Very conservative figures show that at least half of this, or say 20,000,000 tons, was pig iron and scrap handled and used in open-hearth furnaces. This was all handled by the open-hearth charging machine and electromagnet at least once, the bulk of it twice, and a great deal of it three times. By the use of the electric open-hearth charging machine, the direct saving in labor is estimated by one of the large users at 25 cents per ton. This was about 10 years ago, and of course labor is much higher today. At the same time he estimated the indirect saving in handling of the material charged into the open-hearth furnace (calling it only 20,000,000 tons) of $10,000,000. If we go back 17 years, this saving amounts to not less than $85,000,000. This is a big sum of money, but the estimate is far below the maximum amount which has been actually saved. The saving in labor by the use of the electromagnet in the United States per year at the rate pig iron and scrap are being handled today is not less than $1,500,000. We can very safely say that in the last ten years at least five times that amount, or the sum of $7,500,000, has been saved; or a total for both of these inventions of nearly $100,000,000,—a saving of which any inventor might well be proud. Every open-hearth plant of any size in the world today is equipped with these inventions, and they are considered as much a necessary part of the equipment as the furnace itself.

Mr. Wellman's machine for charging open-hearth furnaces with white-hot steel was his greatest contribution to steel making and has been adopted by the steel concerns of the world, earning the inventor international fame. Machinery built under his patents is being used in Great Britain, France, India, Japan, Russia, Spain, Egypt and Germany.

Mr. Wellman was a member of the American Society of Civil

Engineers, the American Institute of Mining Engineers, the British Iron and Steel Institute, the British Institution of Mechanical Engineers and the Cleveland Engineering Society, in which latter he had held the offices of vice-president and president. He was a life member of our Society, joining in 1881, and served it respectively as manager from 1885 to 1888, vice-president from 1896 to 1898, and president in 1901.

At the age of twenty-one Mr. Wellman married Julia A. Ballard at Stoneham, Mass., who died in Cleveland, July 3, 1914. He is survived by two daughters, Mrs. A. D. Hatfield, Mrs. C. W. Comstock, and three sons, W. S. Wellman, president of the Wellman Products Co., and M. C. and F. S. Wellman, of the Wellman Bronze Co.

The funeral service was held Monday afternoon, July 14, at the Euclid Avenue Congregational Church, Cleveland, and was attended by many prominent engineers, manufacturers, and business men. Robert W. Hunt and Ambrose Swasey represented the Society. Members of the Cleveland Engineering Society and delegations from the Wellman-Seaver-Morgan Co., and Wellman Bronze Co. were present.

WILLIAM P. DONOVAN

William P. Donovan, general superintendent of the gasoline department of the Gypsy Oil Co., Tulsa, Okla., died in Philadelphia on May 30, 1919. Mr. Donovan was born on January 7, 1875, in Eagle Rock, Pa., and received his early education in the home schools. His father instructed him in telegraphy and later he attended a business school at Oil City, Pa. While studying there he found time to work as telegraph operator at Smoky Station of the National Transit Co.

WILLIAM P. DONOVAN

In 1892 he entered the employ of the Crescent Pipe Line Co., where he assisted in the construction of an oil-pipe line from Oakdale to Marcus Hook, Pa. He was later promoted to the position of stationary engineer in charge of trunk-line stations on the same pipe line. When the Gulf Refining Co. was organized in 1903, Mr. Donovan became superintendent of distribution at Bayonne, N. J., having also supervision of all additions to the plant. In 1913 he was transferred to the gasoline department of the Gypsy Oil Co., an affiliated concern. Here he designed and constructed plants in Oklahoma, Texas, Louisiana and Mexico for the production of gasoline from casinghead gas. Mr. Donovan was actively interested in the Mid-Continent Section organization. He became a member of the Society in 1916.

HENRY WILLIAM HENES

Harry W. Henes, of the Acme Steel Goods Co., Chicago, died on January 19, 1919. Mr. Henes was born in January, 1887, in New York City, and was educated in the city schools. Later he entered Columbia University from which he was graduated in 1909 with the degree of M. E.

His first position was as structural-steel estimator and inspector with A. Bolter's Sons, Chicago, where he remained for about three years, when he became associated with the Dueth-Henes Corporation, manufacturing agents in the same city, as secretary and treasurer. His next connection was with the Stromberg Motor Devices Co., also in Chicago, first as assistant purchasing agent and later as sales engineer. In July 1918 he became associated with the Acme Steel Goods Co. in charge of the manufacture of nailless box-strapping tools. Mr. Henes was a member of several social clubs in Chicago. He became a junior member of the Society in 1909.

GEORGE ROBERT SHEPHEARD

George R. Shepheard, chief engineer of the Viscose Co., Marcus Hook, Pa., died on May 1, 1919. Mr. Shepheard was born on October 24, 1889, in Wilmington, Del., and received his early education in the Wilmington schools, while his later training was obtained through home study and courses in the International Correspondence Schools. He was connected at various periods in his career with the following concerns: the Taylor Iron & Steel Co., High Bridge, N. J., the Edgar Allen American Manganese Steel Co., New Castle, Del., the J. Morton Poole Co., Wilmington, Del., and with the E. I. Du Pont Co., also in Wilmington. In 1913 he became associated with the Viscose Co. and in 1916 was advanced to the position of chief engineer. Mr. Shepheard became an associate-member of the Society in 1918.

JULIAN G. GUITERAS

Julian G. Guiteras, Captain, Engineers' Corps, A. E. F., France, died of pneumonia on October 12, 1918, in Base Hospital, No. 15, Chaumont, France. Captain Guiteras was born on November 14, 1889, in New York City. He was graduated from Columbia University in 1913 with the degree of M. E. For several years he was connected with the Cadillac Motor Car Co., Detroit, Mich., as draftsman. Later he was with the Hall-Scott Motor Car Co., West Berkeley, Cal. In January 1917 Captain Guiteras passed successfully his examination for a second lieutenancy in the Regular Army and upon receiving his commission was ordered to Fort Leavenworth for training. Upon the completion of his course there he was promoted to the rank of first lieutenant and assigned to Vancouver Barracks, Washington. Before sailing for France in December 1917 he received his captain's commission. In France he was an instructor in the Pioneer School of Chatillon-sur-Seine and was later ordered to bridge reconnaissance work. It was while on this work that he contracted influenza which developed into pneumonia. Captain Guiteras became a junior member of the Society in 1916.

JULIAN G. GUITERAS

PERSONALS

In these columns are inserted items concerning members of the Society and their professional activities. Members are always interested in the doings of their fellow-members, and the Society welcomes notes from members and concerning members for insertion in this section. All communications of personal notes should be addressed to the Secretary, and items should be received by August 15 in order to appear in the September issue.

CHANGES OF POSITION

MAJOR HUGO DIEMER, Ordnance Department, U. S. A., has resigned as professor of industrial engineering at Pennsylvania State College to accept the position of superintendent of personnel with the Winchester Arms and Manufacturing Company, New Haven, Conn.

R. L. ROWLEY, former advisory engineer to the district plant engineer, United States Shipping Board, S. P. District, San Francisco, Cal., resigned on April 15 and is now associated with the survey and engineering department of Johnson and Higgins, San Francisco, Cal.

C. BATEMAN SWASEY is no longer connected with the Gorham Manufacturing Company of Providence, R. I., where he was engaged as superintendent of the Allen's Avenue plant, but is now associated with the Belcher Malleable Iron Company, of Easton, Mass., in the capacity of treasurer.

R. RENTON HIND has resigned as consulting engineer for the America Factors, Ltd., Honolulu, and has assumed the duties of manager of the Pampanga Sugar Mills, Del Carmen, Pampanga, P. I.

ANNOUNCEMENTS

MORRIS KNOWLES has concluded his engagement as chief engineer of the Housing Department of the Emergency Fleet Corporation, United States Shipping Board, and has returned to Pittsburgh, Pa.

J. E. MUHLFELD and V. Z. CARACRISTI announce the formation of Railway and Industrial Engineers, Inc., with offices in New York, with a competent staff of experts thoroughly familiar with domestic and foreign methods and practices.

LIEUT.-COLONEL HENRY M. BYLLESBY, Signal Corps, U. S. A., president of H. M. Byllesby and Company, has had the English Distinguished Service Order conferred upon him.

E. E. MAHER announces the formation of the Maher Engineering Company with offices in Chicago, to handle the sales and installation of Erie Engine Works high-speed engines, the Sims Company feed-water heaters, Dayton-Dowd Company centrifugal pumps, Wagener Steam Pump Company pumps and Pratt Engineering and Machine Company fertilizer and sulphuric-acid machinery.

PETER M. SMITH, until recently in France as a lieutenant in the Signal Corps, is again associated with the Standard Engineering Company, Ellwood City, Pa., in the capacity of chief draftsman.

H. B. PRINDLE has opened an office in New York, as engineer, appraiser and adjuster of railroad loss and damage claims.

GEORGE S. BARKER, formerly First Lieutenant, Aircraft Armament Division, Air Service, A. E. F., has received his discharge and is now connected with the Farnsworth Company, Conshohocken, Pa., in the capacity of mechanical engineer.

LIEUT-COLONEL ELMER K. HILES, Engineers, A. E. F., who went over as Captain in the 15th Engineers, has just returned after nearly two years' service in France, and has joined the Pittsburgh Testing Laboratory as manager of laboratories, with headquarters in Pittsburgh.

CHRISTIAN GIRL, president of the Standard Parts Company, Cleveland, has been awarded the Distinguished Service Cross by the War Department in appreciation of the aid he rendered in developing the Standard Government motor truck.

H. H. ESSELSTYN, commissioner of public works of Detroit, Mich., has resigned, to return to the firm of Esselstyn, Murphy and Hanford, engineers and architects, Detroit. His resignation was made necessary by the increased scope of the work of the company.

MILTON F. FLEWELLING, JR., has been released from the U. S. Navy on inactive duty as engineering ensign, and has been detached from the U. S. S. *Chinampa*. He has accepted the position of chief draftsman for the Ashton Valve Company, Boston, Mass.

ROBERT W. HUNT has been made an Honorary Member of the American Society for Testing Materials.

MAJOR THOMAS H. ALLEN has returned from France after two years' service with the American Expeditionary Forces and will assume his practice as consulting engineer, Memphis, Tenn.

F. E. MATTHEWS, specializing in mechanical refrigeration, engaged for the past nine months as an expert on refrigeration by the U. S. Bureau of Markets, Washington, D. C., having to do with problems dealing with food storage and distribution under war conditions, has returned to his home at Leonia, N. J., preparatory to resuming civilian engineering work in New York.

CHARLES L. ALLEN has been made president and general manager of the Norton Company, Worcester, Mass., when the company recently took over its subsidiary the Norton Grinding Company. Mr. Allen was treasurer and general manager of the company for some time. WILLIAM LACOSTA NEILSON, Leicester, England, foreign manager, and CARL F. DIETZ, general sales manager, have been made vice-presidents, newly-created offices of the new Norton organization. CHARLES H. NORTON, for many years chief engineer of the Norton Grinding Company, has been chosen chief engineer of the grinding machine department of the Norton Company under the reorganization plan.

C. B. LORD has resigned as general superintendent of the Wagner Electric Manufacturing Company, St. Louis, Mo., and, after a period of rest, will assume the position of consulting mechanical engineer to the company.

JOS. J. NELIS, for the past year with the Engineering Section, Emergency Fleet Corporation, Philadelphia, Pa., has accepted a position with the Power Specialty Company, New York, as marine representative for Foster boilers, superheaters and air heaters.

MYER M. SHUSTER who has been discharged from the Naval Air Service has associated himself as production engineer with the Clip-Bar Manufacturing Co., of Philadelphia, manufacturers of the Shuster Speed Wrench.

APPOINTMENTS

HERBERT S. EADES, formerly assistant mechanical engineer, American Bridge Company, Ambridge, Pa., has been appointed assistant mechanical engineer of the Pencoyd, Pa., plant of the company.

L. C. SPRAGUE, formerly district manager of sales at New York, Chicago Pneumatic Tool Company, has been appointed manager of western railroad sales, with headquarters at Chicago, Ill.

DISCUSSION AT RESEARCH SESSION

(*Continued from page 671*)

funds. The securing of funds, however, for doing this work was, he believed, the smallest problem and the securing of men to do the work, the greatest. He was decidedly in favor of private or semi-private research work, but not for Federal control.

Albert Kingsbury urged a careful consideration of the resolution. There were many members of the Society, he said, who were not present at the meeting, and it seemed to him rather inadvisable to take action which would construe the whole Society as against any particular policy. He therefore suggested that the report of the Chicago Committee be brought to the attention of all members of the Society through suitable means of publication. Certainly a large number of the members were interested in the matter and they ought to receive consideration. Those present constituted but a small part of the Society and they ought not therefore to commit the entire membership to any action the meeting might take. His suggestion, therefore, was that the very interesting and valuable report of the Chicago Committee be published in MECHANICAL ENGINEERING and that no definite action be taken by the meeting.

Replying to Mr. Kingsbury's objections, Doctor Mees called attention to the fact that the resolution as offered spoke only of "the sense of the meeting" and the Society could do as it chose in the matter, and the action of the meeting would not be binding upon any one. The resolution was then put to final vote and passed.

DISCUSSION AT GAS POWER SESSION

(*Continued from page 681*)

given up the problem of getting a good sample of a wet mixture, he said, and devoted his attention to using a dry mixture instead. The statement he had made that the best performance was secured with an air temperature of 80 deg. was to be understood to have been so when the temperature of the water in the cylinders was about 200 deg., that is, under definite running conditions.

Some one had asked whether in his experiments with the hot spot any deposit of carbon had been noticed at the higher temperature and regarding this he would say that he had not run tests under those conditions for longer than thirty or forty hours without changing the hot spot in some way or other, and that therefore he had not observed any appreciable deposit at any time. He felt, however, that with the heavier oils a deposit was likely to collect after a certain time.

ENGINEERING RESEARCH

(*Continued from page 695*)

Machine Tools F1-19 Metal-Cutting Tools. Bibliography from 1903 to 1918. Search 2546. A bibliography of 21 pages. Address A. S. M. E., 29 West 39th St., New York.

Manufactures F1-19 Recovery of Oil from Cotton Seed Cake. A bibliography of 2 pages. Search 2565. Address A. S. M. E., 29 West 39th St., New York.

Manufactures F2-19 Making Up Paper Boxes and Containers. A bibliography of 2 pages. Search 2582. Address A. S. M. E., 29 West 39th St., New York.

Marine Engineering F1-19 Steel or Wood Paddle Steamers or Barges for River Use. A bibliography of 5 pages. Search 2489. Address A. S. M. E., 29 West 39th St., New York.

Metal Manufactures F1-19 Taper Holes in Draw Plates. A bibliography of 1½ pages. Search 2550. Address A. S. M. E., 29 West 39th St., New York.

Petroleum, Asphalt and Wood Products F2-19 Dehydration of Oils by Electric Means. A bibliography of 3 pages. Search 2467. Address A. S. M. E., 29 West 39th St., New York.

Pumps F1-19 Rubber Lining for Centrifugal Pumps. A bibliography of 2 pages. Search 2551. Address A. S. M. E., 29 West 39th St., New York.

LIBRARY NOTES AND BOOK REVIEWS

THE BLIND. Their Condition and the Work Being Done for Them in the United States. By Harry Best. The Macmillan Co., New York, 1919. Cloth, 6 x 8 in., 780 pp., illus., tables, $4.

The particular sections of this comprehensive survey likely to interest engineers are those treating of the industrial employment of the blind and of indemnities for the loss of sight. Both topics are given full consideration. Attention is given to the theoretical aspects of industrial establishments for the blind, the organization and results of present establishments, and the possible and present employment of the blind in general occupations. The payment of indemnities through suits at law, insurance policies and workingmen's compensation acts is also described very fully.

BOILER CHEMISTRY AND FEED-WATER SUPPLIES. By J. H. Paul. Longmans, Green and Co., New York, 1919. Cloth, 6 x 9 in., 242 pp., 1 pl., tables, diag., $4.50.

The lack of any adequate discussion of the chemical reactions which occur in high-pressure boilers fed with natural waters, and of the effects of these reactions upon the steaming capacity of the boiler and upon the metal of which it is made, have led the author to prepare this volume, in which he gives the knowledge gained by long practical experience with boilers under varied circumstances and conditions. As far as possible, he has stated the facts and his conclusions in the language of everyday life.

THE CANADIAN MINING MANUAL, 1918. A Handbook of Information Concerning the Minerals and Mines of Canada. Edited by Reginald E. Hore. Mines Publishing Co., Toronto (copyright 1919). Cloth, 9 x 11 in., 352 pp., illus., pl., por., maps, tables, diag., $5.

This is the fourth edition of this handbook of Canadian minerals, metals, mining and metallurgical companies, in which the chief objects are to present concisely matters of interest to persons connected with the mining industry, and to attract attention to the possibilities of Canadian mineral resources. A preliminary survey of progress in 1918 and a summary of the official reports for 1917 are given for each province and product. There are also a number of special articles on topics of interest, a directory of mining companies and a list of the producers of various mine products.

THE ELEMENTS OF ASTRONOMY FOR SURVEYORS. By R. W. Chapman. J. B. Lippincott Co., Philadelphia, 1919. Cloth, 6 x 8 in., 247 pp., tables, 56 diag., $1.75.

The author of this small volume has attempted to provide students of surveying with an elementary exposition not only of the practical methods of observation and computation, but also of the main principles by which the formulæ are derived. The methods of observation are illustrated by fully worked out actual observations and prominent attention is given to the effects of observational and instrumental errors.

ENGINEERING DESCRIPTIVE GEOMETRY AND DRAWING. A Treatise on Line Drawing, Descriptive Geometry, and Engineering or Mechanical Drawing, for the Use of Midshipmen at the United States Naval Academy. By Frank W. Bartlett and Theodore W. Johnson. John Wiley & Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 617 pp., illus., pl., tables, $5.50.

This volume consists of three independent treatises on Line Drawing, Engineering Descriptive Geometry, and Engineering Drawing. Collectively they represent the course in drawing at the United States Naval Academy and are intended to provide a complete course for students with no previous knowledge of mechanical drawing.

Part One has been written to replace Bartlett's Mechanical Drawing. Part Two which treats of the science of orthographic projection, was issued as a separate work in 1910 and has been revised to date. Part Three, the work of Professor Johnson, deals with the application of Parts One and Two to the needs of engineers, draftsmen and mechanics, for practical construction of machines of every kind. Part Three is also issued separately for those who wish a general course in mechanical drawing.

EXCAVATION. Machinery Methods and Costs, Including a Revision of "Excavating Machinery." By Allen Boyer McDaniel. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 560 pp., 209 illus., $5.

Frequent requests for information on recent types of excavators and the newer uses of older types, have led the author of this work to prepare it to replace his "Excavating Machinery," published in 1913. The present work is divided into two sections; the first describes the construction, method and typical cost of operation of each type of excavator, the second is a comparative study of the efficient and economic use of the different types of machines in the various fields of construction work. Highway and railroad construction, reclamation, river, harbor, canal and municipal work, quarrying, tunneling and mining are considered. References to the literature are included.

IRRIGATION ENGINEERING. By Arthur Powell Davis and Herbert M. Wilson. Seventh edition, revised and enlarged. John Wiley and Sons, Inc., 1919. Cloth, 6 x 9 in., 640 pp., 249 illus., 59 tables, $4.50.

The early editions of Wilson's Manual of Irrigation Engineering were especially valuable because of the author's familiarity with large irrigation works in India and Egypt. Subsequent activity in irrigation, particularly in the United States, and developments in related lines of municipal water supply and hydroelectric construction, have presented new problems and evolved new solutions of old ones. Social and economic differences between America and Asia have also caused distinctive changes in practice. In preparing this revised edition Mr. Davis has taken the changed situation into consideration, with the result that the book is in the main rewritten and rearranged, and contains much new material.

LIQUID FUELS FOR INTERNAL-COMBUSTION ENGINES. A Practical Treatise for Engineers and Chemists. By Harold Moore. D. Van Nostrand Co., New York, 1918. Cloth, 6 x 9 in., 215 pp., 49 illus., tables, $5.

The author describes in part one of this volume the chemical differences between the various fuels: petroleum, shale oil, coal and lignite tars, wood and peat distillation products, oils and alcohols, which are used for internal-combustion engines. In part two of the book these fuels are classified according to their suitability for use in engines fitted with carburetors, vaporizers or atomizers. Part three presents methods for the examination and valuation of liquid fuels with a view to their use in these engines, the procedure in such cases being different from that used in determining their value for external combustion.

MAGNETISM AND APPLICATIONS OF MAGNETS. By John D. Ball. (School of Practical Electricity, Book 4). Electroforce Publishing Co., Milwaukee (copyright, 1919). Cloth, 7 x 10 in., 113 pp., 95 illus., tables, $1.50.

This volume which is one of a series of textbooks for technical high schools, trade schools, etc., combines a brief description of the laws and principles of magnetism and the commercial uses of magnets with a selection of laboratory experiments to illustrate the theories of magnetism and electromagnetism. Only elementary mathematics is used.

MOTOR VEHICLE ENGINEERING. Engines (for Automobiles, Trucks, and Tractors). By Ethelbert Favet. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 345 pp., 133 illus., 39 tables, $3.

The present volume, the first of a contemplated series intended to give designers, engineers and students a concise summary of modern practice in automobile design and construction; deals with engines. Only simple mathematics is used.

ACCESSIONS TO THE LIBRARY

The following accessions to the Library of the United Engineering Society are a selection from the large number of books which have been added during the last month. In particular the Library was the recipient of a gift from Mr. Kirby Thomas of some seventy-odd books, catalogs, and pamphlets dealing in great part with mining and mining concerns.

ROTHROCK, J. T., M. D. Areas of Desolation in Pennsylvania. Gift of Pennsylvania Forestry Association.

CAST IRON IN THE LIGHT OF RECENT RESEARCH. By W. H. Hatfield. 1918. Second edition. Purchase.

CENSUS OF MANUFACTURERS. 1914. vol. 1. Gift of Bureau of the Census.

CENTRIFUGAL PUMPS AND SUCTION DREDGERS. By E. W. Sargent. Second edition 1918. Purchase.

COLLOIDAL FUELS. By Lindon W. Bates. 1919. Properties, Tests & Costs.

COLLOIDAL FUEL. Composites of Oil and Carbon. By Lindon W. Bates. 1918. Gift of Submarine Defense Association.

THE CO-OPERATIVES IN RUSSIA. A Power for the Reconstruction of Russia's Economic Life. Gift of Alexander Zelenko.

ECONOMIC PRODUCTION PLUS INDUSTRIAL DEMOCRACY. By C. E. Knoeppel. (Reprint.) Gift of author. Two copies.

ETHICS OF DEMOCRACY. By Louis F. Post. Third edition.

THE FLYING BOOK. The Aviation World Who's Who and Industrial Directory. Edited by W. L. Wade. 1918 edition. Purchase.

GLOSSARY OF ATMOSPHERIC ELECTRICITY TERMS. By W. W. Strong. Gift of author.

HEAT TRANSMISSION TABLES. By W. R. Jones. (Reprint) Gift of The Heating and Ventilating Magazine.

HISTORY OF THE METALLURGY OF IRON AND STEEL. By Sir Robt. A. Hadfield. Gift of author.

THE IMPORTANCE OF ADEQUATE DRAINAGE AND FOUNDATIONS FOR ROAD AND STREET SURFACES. By Clifford Richardson. (Reprint.) Gift of author.

AN IMPORTANT DEVELOPMENT IN THE RAILWAYS OF SPAIN. By F. Lavis. (Reprint) Gift of author.

INDUSTRIAL ELECTROMETALLURGY, including Electrolytic and Electrothermal Processes. By Eric K. Rideal. Purchase.

INDUSTRIAL RESEARCH IN AMERICA. By Raymond F. Bacon, 1916. (Reprint.) Gift of author.

INTERNAL GEAR, THE. The Fellows Gear Shaper Co. *Springfield, Vt., 1919.* Gift of the Company.

AN INTRODUCTORY TREATISE ON DYNAMICAL ASTRONOMY. By H. C. Plummer. *1918.* Purchase.

INVENTIONS AND RECONSTRUCTION. By Lawrence Langner. Reprint from *Printer's Ink.* Gift from author, March 20, 1919.

THE ISTHMIAN CANAL. By H. H. Rousseau. 1909.

JANE'S ALL THE WORLD'S AIRCRAFT. 1918. Founded by Fred T. Jane. *London.* Purchase.

LEGAL AID SOCIETY, THE. 43rd Annual Report for the year 1918. *New York, 1918.* Gift of the Society.

LOS PETROLEOS DEL PERU Y DE PENNSYLVANIA. By Ricardo A. Deustua. *Lima, 1919.* Gift of the author.

MANCHESTER STEAM USERS' ASSOCIATION, THE Memorandum by Chief Engineer for the year 1917-18. Gift.

THE MANUFACTURE OF INTERMEDIATE PRODUCTS FOR DYES. By John Cannell Cain. *London, 1918.* Purchase.

MAPS. Purchase.
- Croquis de los rios Napo y Putumayo por el Coronel D. Pedro Portillo.
- Planta Geral da Cidade de Sao Paulo.
- Planto del rio Tambopata.
- Geologia de las inmediaciones de Morococha, por A. Raimondi. 1861.
- Plano del rio Pastaza.
- Mapa de la Navegacion del alto Maranon. 1913.
- Plano del Cuzco. 1900.
- Plano del rio Amazonas Peruano. 1908.
- Region Oriental del Perú. 1906.
- Plano del rio Huallaga. 1908.
- Mapa Histórico Geográfico de los valles de Paucartambo. 1904.
- Corte Geologico por E. I. Duenas. Siguiendo el Itinerario de Casma á Chacas.
- Carta Geral do Estado de S. Paulo. 1912.
- Plano del rio Manú. 1902.
- Croquis de los Rios Alto Ucayali y Bajo Urubamba. 1904.
- Plano del rio Morona. 1908.
- Plano del rio "Ucayali". 1904.

THE MARINE STEAM TURBINE. By J. W. M. Sothern. Fifth edition, rewritten. *Glasgow, 1918.* Purchase.

MECHANICAL HANDLING OF MATERIAL AND ITS NATIONAL IMPORTANCE DURING AND AFTER THE WAR. By George F. Zimmer. *London, 1917.* Gift of the author.

THE MENACE OF PATERNALISM. By Otto H. Kahn. *1918.* Gift of author.

LES MÉTAUX ET LEURS CONDITIONS D'EMPLOI DANS L'INDUSTRIE MODERNE. 1918. J. Oertlé. Purchase.

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